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THE LARCH SAWFLY, *PRISTIPHORA ERICHSONII* (HARTIG) IN BRITISH COLUMBIA, WITH SPECIAL REFERENCE TO THE COCOON PARASITES *MESOLEIUS TENTHREDINIS* MORLEY AND *TRITNEPTIS KLUGII* (RATZEBURG)[1]

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HISTORY

The European larch sawfly, *Pristiphora erichsonii* (Hartig), has slowly but steadily spread westward in North America since Hagen (6) discovered it in Massachusetts in 1881. In 1883 Fyles (3) reported its appearance in Eastern Canada; during the next 10 years, most of the mature larches in that region were destroyed by it. The sawfly had become well established as far west as Battleford, Saskatchewan, by 1911 and was also present in the Riding Mountain Forest Reserve of Manitoba. It was found in the north from James Bay eastward to Labrador. It was reported from Michigan and Minnesota in 1909.

P. erichsonii was first noted in British Columbia in 1930, by a forest survey party of the British Columbia Forest Service. In an unpublished report by H. J. Hodgins (9) based for the most part on surveys made in 1930, the following entry occurs on page 13: "The larch sawfly was found in abundance in the immature compartment 33 C, Graves Creek." This creek enters the Elk River about 30 miles north of Fernie.

Unfortunately, this infestation was not drawn to the attention of entomologists, and it was not until the summer of 1933 that we knew of the presence of the sawfly. At that time, through the co-operation of the Provincial Forestry Office at Victoria, larvae collected by F. Woodhouse of Fernie were submitted to the Vernon Forest Insect laboratory. These specimens were taken from western larch (*Larix occidentalis* Nutt.) on the Hartley Wilson estate in the city of Fernie. A survey conducted in September 1933 proved that the sawfly was present in the Elk River Valley for a distance of 35 miles north of Fernie, and at least as far westward as Soda Creek, 10 miles west of Elko.

Since then the sawfly has advanced steadily, following the distribution of western larch which is confined to the main river and lake systems. In 1934 more extensive surveys revealed that it occurred from Columbia Lake on the north, southward to Idaho, and from Corbin on the east to Rosen Lake west of Elko. Subsequent examination of terminals at Lumberton showed that eggs had been laid several years previous to 1934. In 1935 it was seen at Kitchener, and the following year was discovered at Boswell

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on the east shore of Kootenay Lake. In 1937 it was found on the east side of Slocan Lake and it reached the northern end in 1939. In 1940 it was present at Whatshan Lakes just west of Arrow Lakes, and by the following year had spread nearly to the summit of the Monashee range adjacent to the road between Edgewood and Vernon. In 1942 it was collected near Vernon in the Okanagan Valley, which is about the western limit of *Larix occidentalis*. Thus it has taken approximately 60 years to spread across the continent. The accompanying map shows the present known distribution of the sawfly in British Columbia in relation to that of western larch.

OBJECT AND METHODS

This article is presented chiefly to show the relative abundance or scarcity of the hymenopterous parasites *Mesoleius tenthredinis* Morley and *Tritneptis klugii* (Ratzeburg) from 1934, up to and including 1942. It also shows the increase in distribution of the sawfly and gives data on the liberations and recoveries of *M. tenthredinis*. An attempt is made to show, in a general way, the extent of conflict between *M. tenthredinis* and *T. klugii* and to clarify some hitherto obscure points in the life history of the latter species.

Factors such as the fungus *Isaria farinosa* (Dicks) Fr., weather effects, destruction by mammals and other predators, have not been investigated individually to any extent. Since *I. farinosa* is known to be saprophytic and is also supposed to be parasitic, it has not been possible to separate the effect of winter killing from that caused by the fungus. In other words the fungus almost invariably invades cocoons in which the larvae have been killed by freezing.

It is also extremely difficult to evaluate the effectiveness of rodents and other mammals. The rodents' habit of gathering the cocoons into caches disturbs the normal distribution of cocoons and affects the accuracy of sampling. The method of identifying cocoons opened by mammals by the type of hole in the cocoon is open to question. There is also no way of knowing whether such cocoons contained living sawfly stages or parasites, unless it can be shown that there is a definite selection on the part of the mammals with regard to cocoon contents. Selectivity of this nature by shrews, but not by rodents, has been indicated by Morris (10) for the European spruce sawfly.

It should therefore, be clearly understood that in Table 2, showing sawfly parasitism and survival, the mortality indicated in column B was due to the combined effects of weather, *Isaria*, and mammals. It may be presumed that the same percentage of parasitism would apply to these cocoons as to those unmolested by the above agents. Consequently these are subtracted from the total number in the sample for purposes of computing percentage of mortality due to *M. tenthredinis* and *T. klugii*.

Collecting of cocoons was carried on from 1934 to 1942 inclusive, with the exception of the years 1937 and 1938. Until permanent plots were established in 1939, mass samples, usually of several thousand cocoons each, were taken from selected areas in the Fernie district. In these earlier samples, parasite recovery was the main object and therefore in collecting an attempt was made to eliminate cocoons destroyed by mammals or

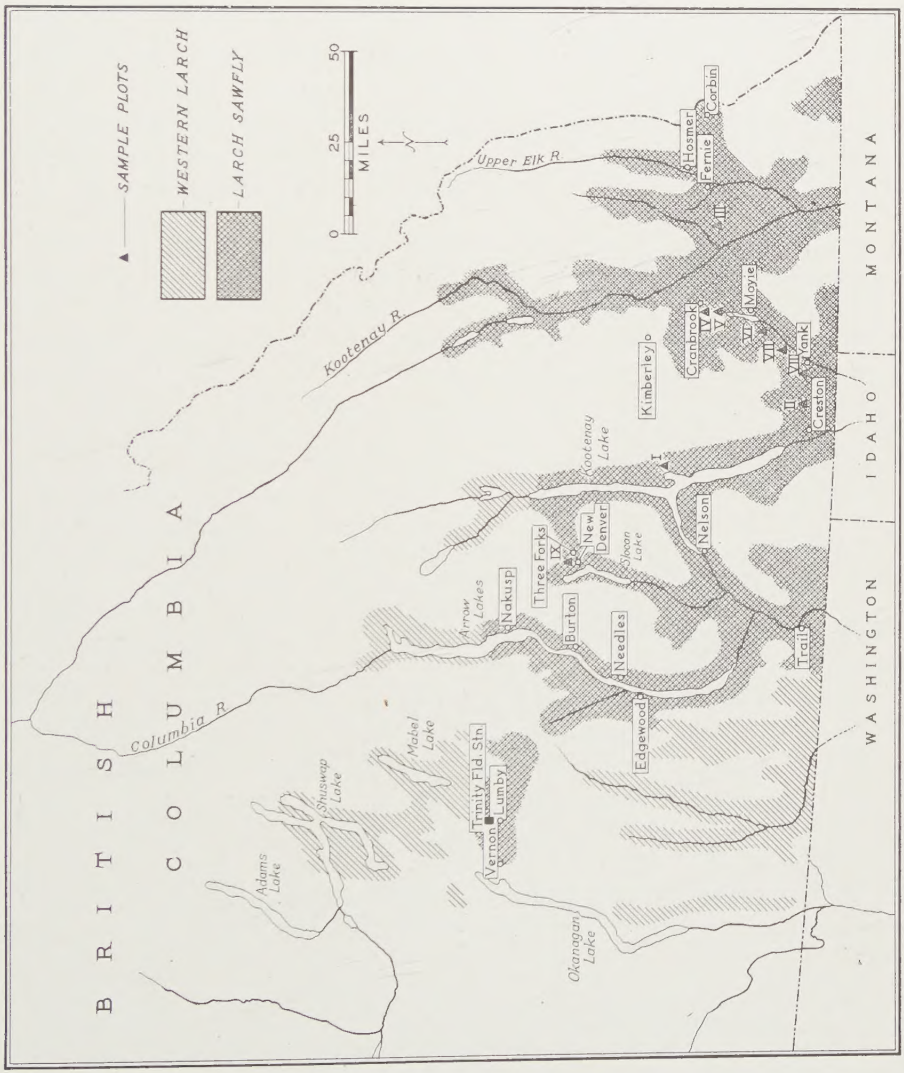

FIGURE 1. Distribution of the larch sawfly.

infected by *Isaria*. Only apparently sound cocoons were taken. Each sample comprised cocoons from beneath 15 to 20 larches ranging in height from 20 to 30 feet. These occurred in scattered, nearly pure stands situated on benches a few hundred feet above the Elk River. The collections were made in the spring before any sawfly emergence had started and the cocoons were placed in cages at a temporary field station (Lizard Creek) near Fernie. Emergence occurred under conditions of air temperature and humidity. The adult sawflies and parasites were removed as they emerged until no more appeared. The remaining cocoons were then examined to determine the contents.

In 1939, nine sample plots were established, located as shown on the accompanying map. These varied from $\frac{1}{4}$ acre to 1 acre in area, according to the character of the stand. The number of larch trees per plot varied from 35 to 185. Nearly pure stands of larch occupied the plots, the trees ranging in height from 10 to 75 feet and in diameter from 2 to 14 inches. The sampling was carried out in 1940 and 1941 in the spring of the year before any emergence had taken place.

The method used was to take 2 samples, each 1 foot square, beneath every tenth tree on each plot, to a soil depth where no more cocoons could be found. Each sample was taken approximately midway between the trunk of the tree and the point directly beneath the outer edge of the crown. If the first 2 samples were taken on the east and west sides of a tree, respectively, the next 2 were taken on the north and south sides, alternating in this manner throughout the plot. Wooden frames were used to measure the sample area and the edges were cut through with narrow-bladed trowels. Each sample of duff was broken into fine pieces over a square of white canvas. The soil portion of each sample beneath the duff was screened for cocoon recovery. Samples were examined within 2 weeks after collecting.

In this sampling work an attempt was made to identify cocoons opened by mammals as well as to record those infected by *Isaria* and those parasitized by *M. tenthredinis* and *T. klugii*. Mass samples were taken near 1 or 2 of the plots where cocoons were numerous, in an attempt to establish the presence or absence of *M. tenthredinis*. These were handled in much the same way as the Fernie samples.

For the purposes of this article, detailed plot descriptions and sample analyses seem unnecessary and only a summary of results is given in Table 1.

The random samples taken in 1942, on the sample plots and in other localities, were collected in the fall of the year and were examined shortly after collection. These also were chiefly intended to show the numbers of *M. tenthredinis* found by dissection and the numbers of cocoons attacked by *T. klugii*.

Work on the life history of *T. klugii* was carried out under air temperature and humidity conditions in the insectary at Trinity Valley Field Station, 22 miles from Vernon. For mass rearings, jelly jars were used containing 100 cocoons each and covered with fine woven cloth. For individual rearing, large vials were used, stoppered with cotton.

TRITNEPTIS KLUGII (RATZEBURG)

One parasite which has accompanied the sawfly in its westward spread is the chalcid, *Tritneptis klugii* (Ratzeburg). The taxonomy of this species is given by Gahan (4). The biology is well discussed by Hewitt (7, 8) under the name *Coelopisthia nematicida* Packard, and the description and much of the life history need not be repeated. However, one point not determined is the number of generations which may occur in a season. This was investigated in 1941, using single lines of descent. Cocoons used for the first spring emergence were collected near Slocan Lake in the fall of 1940.

Seven lots of 25 parasitized cocoons each were used. The first generation of adults emerged between June 5 and 25 with the peak on June 13. A total of 6,120 *T. klugii* were recovered, giving an average of 35 per cocoon. The highest average for any individual lot was 42.1, the lowest, 26.

For second and third generation rearings, 5 lots of 5 cocoons each were used. Adults of the second generation emerged between July 12 and 25, with the peak between July 13 and 18. A total of 1,648 adults emerged, averaging 65.8 per cocoon. The highest average for a single lot was 82.2, the lowest, 15.

Third generation adults emerged between August 11 and 19 with the peak between August 13 and 16. They numbered 1,127, an average of 45 per cocoon. The highest average per cocoon for any lot was 65.8, the lowest, 15. These chalcids laid eggs in new lots of cocoons but no further emergence of adults took place in 1941. This indicates that it is possible to have 3 generations of *T. klugii* a year in British Columbia. The scarcity of full cocoons between the emergence of adults and the time new cocoons become available probably limits the numbers of second and third generation parasites to some extent. However, new cocoons are present in some years before the peak of sawfly emergence, while pupae in old cocoons are still available. Usually there are also some cocoons containing larvae in diapause. In 5 localities near Fernie in 1935, diapause ranged from 0.64 to 22.2% in the mass samples.

Hewitt (7, 8) estimated that because a summer brood only required about 23 days to develop, it would be possible to have 6 broods between the latter part of May and the beginning of October. In British Columbia, the shortest developmental time required to produce 1 summer generation under air temperature and humidity conditions was 29 days. It is not probable, therefore, that 6 generations could occur here under field conditions. Also, the elapsed time between emergence and the findings of suitable cocoons in which to oviposit would tend to limit the number of broods, especially where the cocoon population is low.

The percentage of males in the above 3 generations varied from 13 to 15. Females can reproduce parthenogenetically, but in such cases all of the progeny are males. These males are, on the average, larger than those produced from cocoons containing both males and females. In confinement females will live 2 weeks without food; males die sooner.

MESOLEIUS TENTHREDINIS MORLEY

The ichneumonid parasite, *Mesoleius tenthredinis* Morley, was first released in British Columbia in July 1934. The specimens were received from the Dominion Parasite Laboratory at Belleville, Ontario, where they had been reared from cocoons collected at Parke Reserve, Quebec. Three lots were received totalling 721 males and 406 females. Of these 393 males and 280 females were alive and active on arrival and were liberated at one point on Lizard Creek, 2 miles from Fernie. Subsequent liberations were made as follows:

	Males	Females
1935 Rosen Lake	100	189
Hosmer	1,057	626
1936 Lizard Creek	37	56
Rosen Lake	84	145
Lumberton	55	50
Kitchener	182	206
1941 Fire Valley (Edgewood)	331	284
1942 Fire Valley	143	147
Shuswap River	190	184

Thus a total of 2,572 males and 2,167 females have been liberated. There is some evidence that this parasite was not present in the Fernie region prior to liberations of eastern material. In 1933 the most intensive sawfly infestation was in the immediate vicinity of Fernie. In September of that year 1,600 cocoons were collected on the Wilson estate by W. G. Mathers and overwintered in soil at the Vernon laboratory. Emergence from these cocoons the following spring failed to produce any *Mesoleius* and examination of the remaining cocoons was also negative. On June 8, 1934, H. B. Leech collected 78 cocoons on the Lizard Creek area and shipped them to Belleville, Ontario. On August 13 and 14 of the same year, H. B. Leech and G. R. Hopping collected on the Wilson property and shipped 5,200 cocoons to Belleville. Mr. A. B. Baird reported that examination of emerged and unemerged material failed to to show any *Mesoleius*. On the other hand, Dowden (1) reports the recovery of *M. tenthredinis* and other species of parasites from larch sawfly cocoons collected in 1935 along the north fork of the Flathead River, in northern Montana. This sawfly infestation, which extended into British Columbia, is only about 40 miles in a direct line from Fernie.

CONFLICT BETWEEN M. TENTHREDINIS AND T. KLUGII

At Fernie, in 1935, *M. tenthredinis* was sometimes parasitized by *T. klugii*. Evidence has indicated that this conflict, in some cases, is enough to reduce the effectiveness of *M. tenthredinis* rather seriously, *T. klugii* being able to parasitize larvae, pupae, and even teneral adults of the ichneumonid. The larvae of *T. klugii* complete their growth and emerge successfully, though the number per cocoon is greater when the sawfly is the host.

On the upper Elk River in 1935 *T. klugii* parasitized 59 out of 156 *M. tenthredinis* in a sample of 2,081 cocoons. On the same area in 1936, this hyperparasitism amounted to 36 out of 955. In 1942, on plot VI, *T. klugii* parasitized 9 out of 40 *M. tenthredinis*. These samples represent the highest observed hyperparasitism by *T. klugii*. In view of the fact that *M. tenthredinis* attained a parasitism of 88% at Treesbank, Manitoba, in 1927, where *T. klugii* was apparently absent, it may not be advisable to introduce the latter species into areas containing *M. tenthredinis*. However, it does seem advisable to establish *M. tenthredinis* on areas where *T. klugii* is already present, since the latter alone has not attained a parasitism over 50% in our mass samples, while the 2 parasites together have attained over 70% parasitism in mass samples from several different areas. The general impression obtained from the sample data is that total parasitism of the sawfly cocoons has been increased by the introduction of *M. tenthredinis* into British Columbia.

BESSA SELECTA MEIGEN

The tachinid, *Bessa selecta* Meigen, was already present in the Fernie region in 1934. Of 924 larch sawfly larvae collected that year, 47 had *Bessa* eggs on them, but only 15 adults were reared. The following year an increase was indicated since 94 larvae collected on the same area had 54 *Bessa* eggs on them. Since then this parasite has been relatively scarce.

The flies seem to prefer third and fourth instar larvae on which to oviposit. As many as 6 eggs have been found on 1 larva but the usual number is 1 or 2. Two liberations of *B. selecta* totalling 2,511 males, and 3,189 females were made in 1942, one on July 4 in Fire Valley near Edgewood, and one on July 7 near the Shuswap River, 24 miles east of Vernon.

Two specimens of another tachinid, *Phorocera* sp., have been reared from the larch sawfly in British Columbia, 1 from the upper Elk River and 1 from Corbin.

ZENILLIA NOX HALL

In 1935, 872 adults of a Japanese sawfly parasite, the tachinid *Zenillia nox* Hall, were released, 116 at Rosen Lake and 756 at Hosmer. No field recoveries have been made and it is doubtful that the species became established.

ISARIA FARINOSA AND WEATHER

At Hosmer in the spring of 1936, over 70% of the sawfly cocoons were infected with *Isaria farinosa* (Dicks) Fr., but it was impossible to distinguish those which might have been killed by the fungus from those which had been killed by low temperatures (−2° to −14° F. from October 30 to November 3) of the previous year. The ground at that time had no cover of snow and the mortality in the cocoons must have been high, but the invasion of the cocoons by *Isaria* obscured this effect. However, *Isaria* has been present every year samples were taken. In 1934 the percentage of cocoons affected varied from 1% on dry shallow soil covered by thin duff to 9% on moist sites with thick duff. There is some evidence to show

that *Isaria* is the primary cause of death in at least some instances. In the samples collected in the Fernie district in 1934 the fungus continued to spread to apparently healthy cocoons after collection.

PREDATORS

Predators appear to be less important than parasites in reducing the sawfly population. "Yellow-jackets" (*Vespula* spp.) prey on the caterpillars to a limited extent. The larvae of an elaterid beetle, *Ludius lutescens* Fall, are numerous at times in the duff and several, found partly inside cocoons, were eating the larvae. They had obviously made their own entrance holes.

Only 1 species of bird, *Turdus planesticus propinquus*, the western robin, was observed to eat the sawfly larvae.

Small mammals such as mice and shrews feed quite extensively on larvae in cocoons, particularly during winters with deep snow which remains later than usual in the spring. Large caches of opened cocoons beneath logs and at intervals along the winding tunnels testify to this. Usually the duff has been searched for cocoons for an inch or more on each side of such tunnels.

DEFOLIATION

Defoliation of each tree on the sample plots has been recorded every year since 1939 and supplementary notes have been taken covering the general infestation. Criteria used for judging defoliation were as follows:

Light— No noticeable defoliation; some terminals curled by egg-laying detected after a few moments inspection.

Medium—Upper third of crown noticeably thin. Curls fairly numerous.

Heavy— Half or more of crown practically stripped of needles. Curls numerous.

In 1933 heavy defoliation occurred on rather limited areas from 4 miles northeast of Fernie, westward to Lizard Creek. Other areas showed light to medium defoliation. The following year defoliation was heavy at Lizard Creek, Hosmer, on the upper Elk River, at Corbin and Sand Creek, west of Elko. On all other areas it was light to medium. In 1935 defoliation was very light over the entire area of sawfly distribution. This was unexpected in view of the sawfly survival and the extensive egg-laying noted. Extremely wet weather during hatching and young larval stages may have caused a high mortality before any heavy feeding could occur. Defoliation was again generally light from 1936 to 1938, inclusive. No appreciable defoliation occurred in 1937 and it was difficult to find any cocoons. Egg scars on new shoots were very scarce.

In 1939 defoliation was light from Slocan Lake eastward to the west side of Kootenay Lake. It was medium to heavy from Grey Creek on the east shore of Kootenay Lake eastward to Cranbrook. East of this point it was light to medium. In 1940 areas of heavy defoliation had shifted to

the Slocan Lake region, particularly on Carpenter Creek. Areas from there eastward were generally light. In 1941 defoliation was again medium to heavy around Slocan Lake but light on other areas. In 1942 the centre of heavy defoliation again shited westward to areas more recently invaded by the sawfly. The heavier defoliation occurred along Arrow Lakes and it was medium to heavy in Slocan Valley. It was light to medium in the Nelson district and at Grey Creek. From Creston eastward to the Fernie region defoliation was light.

Five larch trees have died on the sample plots since 1931. These trees were all 6 inches or under in diameter and were obviously suppressed trees. Although defoliation by the larch sawfly may have been the immediate cause of death, the indications were that these trees would have been killed in a few years by shading out.

SUMMARY AND CONCLUSIONS

The parasites *M. tenthredinis* and *T. klugii* are well distributed over the areas infested by the European larch sawfly and they are important control factors. While there is some conflict between the two owing to hyperparasitism of *M. tenthredinis* by *T. klugii*, this does not appear to be serious in most cases. It seems to be advantageous to introduce *M. tenthredinis* into areas where *T. klugii* is already present but the reverse is not recommended until more is known about the inter-relationship of the 2 parasites.

The tachinid, *Bessa selecta* Meigen, is widespread but not so important as the above 2 species. The fungus, *Isaria farinosa* (Dicks) Fr., may be valuable under certain moisture conditions. Predators are less effective than parasites. Weather may have been a control factor in 1935.

In British Columbia the general indication is that defoliation has been heavy during the first few years after the sawfly has become established. After that, zones of heavy defoliation have decreased in number and size. It may be that natural control factors now operating over much of the sawfly area of British Columbia will be able to keep the sawfly population down sufficiently to prevent any lasting damage to the western larch stands.

ACKNOWLEDGMENTS

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TABLE 1.—SAWFLY MORTALITY BASED ON SAMPLE PLOT DATA

Year	Plot no.	No. of samples	A	B	C	D		E		F	Parasitized by				Sawflies surviving	
			Total no. cocoons examined	Old cocoons	A minus B	Openeed by rodents		Infested by *Isaria*		C minus (D + E)	*Tritneptis*		*Mesoleius*			
						no.	%	no.	%		no.	%	no.	%	no.	%
1940	1	11	195	50	145	19	13.1	16	11.0	110	81	73.6	0	0.0	29	20.0
	2	15	13	3	10	7	70.0	0	0.0	3	3	100.0	0	0.0	0	0.0
	3	14	4	0	4	3	75.0	0	0.0	1	1	100.0	0	0.0	0	0.0
	4	15	28	9	19	2	10.5	4	21.1	13	7	53.8	0	0.0	6	31.6
	5	18	53	16	37	19	51.4	13	35.1	5	2	40.0	1	20.0	2	5.4
	6	12	119	36	83	6	7.2	38	45.8	39	30	76.9	0	0.0	9	10.8
	7	12	572	62	510	66	19.4	234	45.9	210	90	42.8	4	1.9	116	22.7
	8	6	95	43	52	18	34.6	13	25.0	21	19	90.5	0	0.0	2	3.8
	9	12	9	0	9	2	22.2	2	22.2	5	1	20.0	0	0.0	4	44.4
	Totals	115	1,088	219	869	142	16.3	320	36.8	407	234	57.5	5	1.2	168	19.3
1941	1	11	233	75	158	50	31.6	55	34.8	53	51	96.2	0	0.0	2	1.3
	2	10	10	3	7	2	28.6	2	28.6	3	3	100.0	0	0.0	0	0.0
	3	14	5	3	2	0	0	0	0.0	2	2	100.0	0	0.0	0	0.0
	4	15	21	5	16	8	50.0	1	6.3	7	4	57.1	0	0.0	3	18.7
	5	18	64	20	44	7	15.9	24	54.5	13	13	100.0	0	0.0	0	0.0
	6	12	125	20	105	15	14.3	44	41.9	46	39	84.8	0	0.0	7	6.7
	7	10	190	22	168	37	22.0	84	50.0	47	35	74.5	0	0.0	12	7.1
	8	LOGGED IN 1940														
	9	12	6	1	5	0	0	240.0		3	1	33.3	0	0.0	2	40.0
	Totals	102	654	149	505	119	2.36	21242.0		174	148	85.1	0	0.0	26	5.1

TABLE 2.—SAWFLY PARASITISM AND SURVIVAL BASED ON RANDOM SAMPLES

Year	Locality	A	B	C	D				E	F	
		Total no. cocoons examined	Mortality from causes other than insect parasites	A minus B	Parasitized by				Dipterous parasites	Sawflies surviving	
					Tritneptis		*Mesoleius*				
					no.	%	no.	%		no.	%
1934	Fernie	455	69	386	76	19.7	0	0.0	—	310	68.1
	Hosmer	132	24	108	44	40.7	0	0.0	—	64	48.4
	Upper Elk R	355	69	247	41	16.6	0	0.0	—	245	69.0
1935	Hosmer	2319	1229	1090	204	18.7	9	0.8	—	877	31.7
	Upper Elk. R.	2081	716	1365	117	8.6	156	11.4	1	1091	52.4
	Corbin	335	154	181	15	8.3	9	5.0	1	156	46.6
	Lizard Cr.	1552	595	957	327	34.5	6	0.6	—	624	40.2
1936	Hosmer	3441	2596	845	185	21.9	352	41.6	—	308	8.9
	Upper Elk R.	3313	1683	1630	274	16.8	955	58.6	—	401	12.1
1940	Moyie Lake	1471	673	798	336	42.1	12	1.5	—	126	15.7
1941	Alamo (Slocan Lake)	2497	548	1949	576	29.5	53	2.7	—	1320	52.8
	Plot I	21	0	21	0	0.0	6	28.6	—	15	71.4
	Plot IV	4	0	4	0	0.0	1	25.0	—	3	75.0
	Plot V	50	2	48	3	6.2	13	27.1	—	32	64.0
	Plot VI	150	27	123	49	39.9	40	32.5	—	34	22.6
1942	Plot VII	50	14	36	17	47.2	14	38.7	—	5	10.0
	4.0 mi. S. Grey Creek	132	10	122	7	5.7	59	48.3	—	76	57.6
	8.9 mi. W. Nelson	86	2	84	37	44.0	0	0.0	—	47	54.6
	26.8 m. W. Nelson (Slocan Valley)	50	10	40	14	35.0	0	0.0	—	26	52.0
	28.1 mi. S.E. Nakusp	43	11	32	12	37.5	16	50.0	—	4	9.3
	10.9 mi. S. Nakusp	50	1	49	0	0.0	3	6.1	—	46	92.0
	1.0 mi. S. Burton	50	3	47	1	2.1	7	15.0	—	39	78.0
	2.5 mi. N. Needles	42	2	40	0	0.0	4	10.0	—	36	85.7
	9.0 mi. W. Edgewood	50	12	38	3	7.9	1	2.6	—	34	68.0
	16.0 mi. W. Edgewood	50	3	47	6	12.7	2	4.3	—	39	78.0
	Trinity Field Station	36	1	35	0	0.0	0	0.0	—	35	9.7

THE IRON CONTENT OF BUTTER AND ITS RELATION TO THE BUTTER WASH WATER[1]

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Considerable attention has of late been given to the iron content of butter (Davies (2), Williams (11), Moir and Andrews (7)).

Milk is reported (5) to contain 0.31 to 0.44 p.p.m. of iron as it leaves the cow and this is considered a deficiency from the human nutritional point of view. On the other hand, cream as received at the creamery for churning purposes often contains considerable amounts of this metal, presumably the result of the contact of the milk and cream on the farm with exposed iron in utensils, such as pails, separators and shipping cans. Although the creameries have made great strides towards the elimination of iron in their equipment, one may still observe vats of tinned galvanized iron for holding cream, rusty churn door frames, bolts, etc. Thus the addition to the cream of iron from creamery equipment cannot be excluded as a possibility.

Not infrequently the creamery receives a shipment of cream containing sufficient iron to lend to it a metallic taste. Such cream is shunned by the buttermaker as he realizes that he has no means of preventing the defect from being carried over into the butter, that the butter will receive a low initial score and that in addition it possesses poor keeping quality.

Aside from metallic butter due to the presence of considerable amounts of iron, the catalytic action of relatively small quantities as a factor in promoting such butter defects as tallowy, oily, fishy, storage flavours and other defects of an oxidative nature is well recognized.

As most of the butter produced in Alberta is made during the summer months, much of it has to be held in cold storage for considerable time. Consequently, any agent such as iron, having a deteriorating effect on the butter under storage conditions becomes of marked significance.

It was with these thoughts in mind that a survey of the iron content of Alberta creamery butter was started. This survey covered 27 creameries and a total of 146 churnings.

ANALYTICAL METHODS

In principle, the thicoyanate method of Thomson (10) was employed.

Twenty-five g. lots of butter, in duplicate, were weighed into glazed sillimanite crucibles that had been boiled in concentrated sulphuric acid and rinsed with distilled water. The crucibles were kept submerged in concentrated sulphuric acid when not in use. If they showed signs of corrosion, they were discarded. The butter was placed in an asbestos-lined electrical oven and the temperature slowly raised to drive off the water.

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The sample was then transferred to an open flame from a nickel plated burner and the temperature raised high enough to ignite the fat. Following the suggestion of Davies (2) the charred mass was extracted with water to dissolve out the salt and filtered. The filter paper and residue were returned to the crucible. After ashing, 2 ml. of concentrated nitric acid and 10 ml. of water were added and the mixture gently boiled for ten minutes to dissolve the ash. When cool, the contents were washed into the beaker holding the salt solution, 1 ml. of a 3% hydrogen peroxide solution added and the mixture allowed to stand 10 minutes. It was then filtered into a 50 ml. Nessler cylinder through a filter paper, which had been washed with 1 N. nitric acid. Five ml. of 5% potassium thiocyanate solution were added to the solution in the cylinder, which was then made up to the mark with water and mixed well. Two ml. of concentrated nitric acid, 1 ml. of 3% hydrogen peroxide and 5 ml. of 5% potassium thiocyanate were similarly added to a matched cylinder partly filled with water. An iron solution (9) diluted to contain 0.025 mg. of iron per ml. was introduced from a burette until the colour of the standard matched that of the sample. The level was adjusted to the 50 ml. mark and the reading was taken. One ml. of the iron solution was equal to 1 p.p.m. of iron, when a 25 g. sample was used.

The analyses were usually run in lots of 6, together with a blank. The reading of the blank remained practically constant at 0.2 p.p.m. and duplicates usually agreed very well.

Although no elaborate technique was evolved for eliminating completely iron in the chemicals and other material used, (for instance the nitric acid contained traces of iron) every effort was made to have conditions of analysis as uniform as possible, and the same lots of chemicals and filter paper (No. 00, 9 cm. Munktell) were used throughout. In addition much care was exercised to prevent contamination with iron during analysis. It was the experience that unless these precautions were taken uniform results could not be expected.

From Table 1 it will be noticed that there is a significant difference in the iron content of butter from different creameries. For instance, 6 first grade churnings from Creamery No. 18 had an average iron content of 0.48 p.p.m., whereas, the 6 first grade churnings from Creamery No. 27 showed an average of 2.37 p.p.m. Furthermore, it will be observed that the tendency for the iron content is to remain rather uniform within the same plant, particularly when dealing with first grade butter.

Generally the second and lower grades within the same plant contained more iron than the first grade butter. However, there were many exceptions and some low grade churnings had a low iron content.

New Zealand workers (7, 8), have placed the upper safe limit for the iron content of storage butter at 1.5 p.p.m. When churnings reported in Table 1 are grouped accordingly, we find for first grade butter out of a total of 123 churnings, 91 or 74% contained less than 1.5 p.p.m. and 32 churnings, or 26% contained 1.5 p.p.m. of iron or over. For second or lower grades, of a total of 23 churnings, 11 churnings, or 48% contained less than 1.5 p.p.m. and 12 churnings, or 52% contained 1.5 p.p.m. of iron or more.

TABLE 1.—THE IRON CONTENT OF 146 CHURNINGS OF ALBERTA CREAMERY BUTTER IN PARTS PER MILLION

Cry. no.	First grade butter	Butter below first grade	Fe content of creamery water p.p.m.
1	0.6, 0.6, 2.0, 0.9, 0.8, 1.2, 1.0	1.4, 1.5, 2.7, 0.8	<0.1
2	0.7, 0.6, 0.6, 0.6		0.6 to 0.8
3	2.5, 1.7, 1.6, 2.6, 2.4, 1.4, 2.4, 1.9	2.5	7.0
4	0.8, 0.7	0.6	<0.1 to 0.1
5	1.4, 0.7	0.7	1.7
6	0.8, 1.6, 1.6, 0.8	0.8, 2.5	0.6
7	0.6, 0.6, 1.2, 0.7, 0.6, 0.5, 0.9, 1.1, 0.6		<0.1 to 0.1
8	0.8	0.6	<0.1
9	1.2, 1.2	1.0	<0.1
10	1.0, 0.8		0.6
11	1.4, 1.4, 1.2, 1.3, 0.6, 0.9	0.7	1.4
12	0.9, 1.3, 1.2, 1.1, 1.0, 1.0	2.6	0.4 to 1.6
13	1.2, 1.8, 1.4		1.0
14	0.6, 0.4, 0.4		0.3
15	1.4, 1.4, 1.4		—
16	1.0, 0.7, 0.6, 0.8		<0.1
17	1.5, 1.4, 1.0, 0.9, 1.1, 1.1, 0.8, 1.0	1.4, 1.1	4.0
18	0.4, 0.6, 0.5, 0.5, 0.5, 0.4		<0.1
19	1.5, 1.4, 1.9, 1.6, 1.7, 1.8, 1.7	2.5, 2.1	3.6
20	0.5, 0.7, 0.4		<0.1
21	1.0	2.2, 1.8	0.5 to 0.7
22	1.1, 1.0, 1.0, 1.2, 0.8, 0.8, 1.4, 0.8	1.0	0.6
23	1.2, 1.4, 0.8		0.5
24	1.6, 1.7, 1.6, 1.5, 1.6, 1.9, 1.9		2.8
25	0.6, 0.6, 0.8		0.3
26	1.5, 1.3, 1.3		1.3
27	3.3, 2.7, 2.1, 1.8, 2.3, 2.0	2.9, 1.9, 1.9	7.5 to 10.0

EFFECT OF THE IRON CONTENT OF THE BUTTER WASH WATER

Little is known regarding the iron content of creamery waters and of the effect that it may have on the iron content of the butter.

Sonke Knudsen and Pape (3), state that a creamery water should not contain more than 0.5 p.p.m. of FeO. Other workers (6) cite an instance where a creamery water containing from 9 to 15 p.p.m. of iron was the cause of oily and tallowy butter. Kooper (4), on the other hand observed no detrimental effect from the use of a butter wash water re-constituted from distilled water and ferrous carbonate to contain 36 p.p.m. of iron, and yielding a butter calculated to contain 20 p.p.m. of iron.

For some time the iron content of creamery waters received by this laboratory for analysis has been determined by the procedure laid down in "Standard Methods of Water Analysis" (9). Of the 27 creameries reported in Table 1, iron analysis of the butter wash water was available for all but one creamery and will be found in the last column of Table 1.

Since the result in some cases is based on a single determination, and as there is likely to be a variation in the iron content of the water from time to time, particularly where it is pumped into a storage tank before going to the churn, the figures given should be considered only approximate. Nevertheless, they suggest a relationship between the iron content of the butter wash water and that of the butter.

To gain more definite information on this point, experimental churnings were made at a number of creameries. The plants selected used waters varying in iron content from less than 0.1 p.p.m. to 7.8 p.p.m., but were otherwise quite similar. The experimental procedure was as follows. After churning was completed and the buttermilk drained off, a portion of the butter granules was removed from the churn. The regular churning was then proceeded with as usual, which consisted of giving the butter granules a rinse until the water came nearly clear at the gate. The gate was then closed and enough water run in to float the granules and the churn revolved for a few minutes, the water was then drained off and the butter salted and worked. When the moisture content was low, water was added so as to have a moisture content of the finished butter of from 15.5% to 15.8%.

The butter granules removed from the churn were rinsed and washed with distilled water, worked and finished by hand. An effort was made to copy the regular churning procedure as closely as possible in regard to

TABLE 2.—THE EFFECT OF THE BUTTER WASH WATER ON THE IRON CONTENT OF BUTTER

Creamery	Chg. nos.	Iron content of butter		
		Washed with iron free water	Washed with creamery water	Iron content of creamery water
		p.p.m.	p.p.m.	p.p.m.
A	779	0.9	0.9	<0.1
	780	0.5	0.8	
	782	0.6	0.6	
	916	0.5	0.6	
B	163	0.4	1.05	3.2
	164	0.4	0.95	
	165	0.35	0.9	
C	450	0.6	0.9	0.1 to 0.2
	454	0.5	0.55	
	496	0.45	0.7	
	497	0.4	0.6	
	499	0.4	0.5	
D	609	0.5	0.5	<0.1
	610	0.45	0.45	
	612	0.4	0.4	
E	189	0.4	0.5	<0.1
	190	0.35	0.6	
	191	0.3	0.35	
F	(*a*)	0.65	1.6	2.8
	(*b*)	0.6	1.9	
	(*c*)	0.7	1.3	
G	301	0.4	0.6	0.4
	302	0.4	0.6	
	303	0.4	0.8	
H	246	0.5	1.6	7.8
	247	0.5	1.8	
	248	0.5	1.5	

washing and composition of the butter in order that the only essential difference between the 2 butters would be in the iron content of the butter wash water.

In Table 2 the results obtained from 27 such experiments at 8 different creameries are reported.

It is evident that the iron content of the butter wash water played a role in determining the amount of iron present in the butter. Where the iron content of the water was considerable it became a significant factor.

It will be observed that at creameries having a water low in iron, the iron content of the butter differed but little from that washed with distilled water and that there is a rather consistent tendency for the iron content of the butter to follow that of the water. It is worth pointing out that when the iron content of the water was low or when distilled water was used, the iron content of the butter was consistently less then 1.0 p.p.m. and often below 0.5 p.p.m., and that the butter was made from good quality cream and at plants where contamination from equipment was not likely to be a significant factor. (Creameries E, F and H had churns of the roller-less type.)

DISCUSSION

While the iron content of creamery butter heretofore has been given scant attention, it is likely that more interest will be shown as the butter market becomes more discriminating and the demand for a butter possessing superior keeping quality more pressing.

With our present incomplete knowledge of the effect of iron on butter it is rather difficult to evaluate properly iron analyses of butter, since factors other than total amount of iron evidently are involved. Barnicoat and Palmer (1) have thus recently shown that ferrous iron as compared to ferric is very much more active in catalysing oxidative changes in butter.

The work reported shows considerable variation between creameries in the iron content of their butter and a rather unexpected uniformity within the individual creamery. However, the fact that so many creameries were capable of producing butter with a low iron level gives promise that iron as a factor in butter deterioration may be largely overcome.

In the past much attention has been given to farm utensils as a source of the iron appearing in cream and butter. From the present study it is evident that the butter wash water may also be a factor and at plants where the iron content of the water supply is high, it may become necessary to resort to de-ironizing the water used for buttermaking purposes in order to bring about a reasonably low iron content in the finished butter.

SUMMARY

1. A total of 146 churnings of commercial creamery butter, representing 27 creameries have been analysed for iron.

2. The iron content of the butter ranged from 0.4 p.p.m. to 3.3 p.p.m. Of 123 first grade churnings 74% contained less than 1.5 p.p.m. Of 23 churnings below first grade 48% contained less than 1.5 p.p.m.

3. There was a tendency towards uniformity in the iron content of the butter from the same creamery, particularly for butter of first grade.

4. The iron content of the butter wash water was shown to affect the iron content of the butter.

5. When the butter was washed with distilled water or natural water low in iron, all of the first grade butter examined contained less than 1.0 p.p.m. of iron. An increase in the iron content of the butter wash water was usually accompanied by a higher iron content of the finished butter.

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AN ESTIMATE OF LOSS IN MANITOBA FROM COMMON ROOT ROT IN WHEAT[1]

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INTRODUCTION

Common root rot of cereals, caused chiefly by the fungi *Helminthosporium sativum* P.K. & B. and *Fusarium culmorum* (W.G. Sm.) Sacc., appears to be widespread in Canada and to cause considerable damage to cereals and grasses. These fungi invade the basal parts of the plant and bring about a reduction in tillering, and a stunting or wilting, or even the death of the host.

Losses from common root rot are difficult to estimate. The occurrence of disease in a field appears to be closely related to the physical and chemical structure of the soil, and, therefore, if the soil within a field is extremely variable, there is also a considerable variability in the severity of root rot in different parts of the field. The writer's observations during a 12-year survey, 1930 to 1941 inclusive, showed that common root rot was generally most severe where conditions for growth of the host plants were unfavourable. The following predisposing factors were found to increase the severity of the disease: the planting of frosted or mechanically-injured seed, deep or dense seeding, soil drifting, excessive soil salinity, and, low water-holding capacity of the soil. These findings were corroborated by Shen (3) who showed that low soil moisture, poor nutrition, and high soil acidity foster the development of *Fusarium culmorum* root rot in wheat.

The loss from common root rot has been estimated in various ways. Simmonds (4) studied healthy and diseased plants of wheat and barleys in the field, and found that moderate lesioning on the sub-crown internode reduced the yield from 15 to 20%, and that severe lesioning reduced the yield from 30 to 45%. He did not report any loss from slight lesioning. Edson and his co-workers (2) summarized the individual estimates of loss obtained from field investigators in different parts of the United States. The loss varied in different parts of the country, but in some areas it was as high as 10%. Craigie (1), basing his estimate upon results from experimental plots at Winnipeg, found the annual loss from common root rot in Manitoba to be not less than 5%. Greaney[3] estimated the annual loss for Manitoba at 5%, for Saskatchewan at 9.4%, and for Alberta at 3%. This estimate was based on data obtained from plant disease surveys and from field experiments made by members of the Dominion Laboratories of Plant Pathology located at Winnipeg, Saskatoon, and Edmonton.

In view of the fact that previous estimates of loss from common root rot for Manitoba were based largely upon results obtained from experimental plots in which the conditions in regard to the spacing of rows and

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[3] Unpublished data of Dr. F. J. Greaney, Dominion Laboratory of Plant Pathology, Winnipeg, Manitoba.

methods of cultivation were generally different from those found in actual farm fields, the writer attempted to devise a better method of securing an estimate of loss from common root rot. It was thought that, if the severity of root rot was related to the yield in individual plants, and if a sufficiently large number of plants were studied in several representative farm fields in each soil zone, the estimate of loss from common root rot would be reasonably accurate. In order to measure the loss from common root rot in wheat, 60 wheat fields were studied in Manitoba in each of the 3 years, 1939 to 1941 inclusive. The results of this study are summarized in this paper.

PROCEDURE

In order to secure a reasonably representative estimate of the loss from common root rot in wheat in Manitoba, it was necessary to obtain a large number of random samples of ripe, standing grain from all wheat-growing sections of the province. To aid in the collection of such representative samples, the writer outlined on a good road map of Manitoba the principal soil zones, and, in each soil zone, except in one (A2), which is very large, he selected 10 sampling locations, about equal distances from one another. Twenty locations were selected in the large soil zone.

Each year, as the wheat crop matured, the different sampling locations were visited, and at each location, one field of wheat was sampled. The field was entered to a distance of 50 paces and a sample of plants (all those in a 1-metre length of drill row) was taken at that point. At 9 other points, separated by 50-pace intervals and in a line roughly paralleling the margin of the field and 50 paces within it, other plant samples were taken in the same way. The whole group of 10 samples was then tied in a bundle, which was wrapped and marked with the sampling location number. After the whole wheat-growing area of Manitoba was sampled in this way, the bundles of plants were taken to the laboratory, each bundle was opened, and the plants within each were classified into groups according to the severity of root rot on them. The plants and the spikes in each group from a bundle were then counted. This count permitted, after the groups of plants from each bundle had been threshed separately, the computation of the average weight of grain per plant and per spike for each group.

In calculating the loss in yield for each collection from a field, use was made of the following formula:

$$\text{Percentage loss in yield} = 100 - \left(\frac{W}{W_1 \times N} \times 100\right)$$

where W is the total weight of grain from a collection, W_1 the average weight of grain from individual healthy plants, and N the total number of plants in a collection.

EXPERIMENTAL RESULTS

The average percentages of wheat plants with common root rot and the average percentage reduction in yield for each soil zone in each of the 3 years of the investigation are given in Table 1. The data given in this table indicate a considerable variation between soil zones in the percentage

of diseased plants, and perhaps even a greater difference between years. The percentage reduction in yield is not very closely related to the percentage of diseased plants when the data for individual soil zones in any one year are compared, but there is relatively close agreement in this respect when the data for the whole 3-year period or for all the zones are averaged.

TABLE 1.—THE AVERAGE PERCENTAGE OF WHEAT PLANTS WITH COMMON ROOT ROT AND THE AVERAGE PERCENTAGE REDUCTION IN YIELD FROM THE DISEASE IN DIFFERENT SOIL ZONES IN MANITOBA

Percentage of plants with root rot

Soil zone[1]	Year			Mean
	1939	1940	1941	
A1	29.2	47.3	32.9	36.4
A2 (W)[2]	24.3	50.8	52.8	42.6
A2 (E)	17.2	53.8	43.5	38.1
A3	20.5	65.2	40.2	42.1
A5	21.9	42.6	34.2	32.9
A7	16.2	50.6	46.6	37.8
Mean	21.5	51.7	42.7	38.3

Percentage reduction in yield

A1	11.8	15.5	8.4	11.9
A2 (W)	7.5	15.6	21.7	14.9
A2 (E)	5.7	14.6	9.4	9.9
A3	5.6	13.7	14.1	11.1
A5	10.7	12.8	6.7	10.0
A7	6.7	26.4	12.3	15.1
Mean	8.0	16.4	12.1	12.1

[1] A1 Brown Steppe—Black Earth Transition.
A2 (W) Black Earth—Sandy over large areas.
A2 (E) Black Earth—Red River Valley clay loam.
A3 Northern Black Earth and Degrading Black Earth—Frequently highly salinized.
A5 Degrading Black Earth and grey wooded.
A7 Rendzina (High Lime).
[2] A2 (W) = Western part of A2.
A2 (E) = Eastern part of A2.

In Table 2 are given the average percentages of healthy plants and of those with slight, moderate, and severe root rot. There is much variation in the percentage of healthy plants from year to year, but, for any one year, or for any particular soil zone, the ratio of the percentages of plants with different degrees of disease remains fairly constant; the percentage of plants with slight root rot was about 2/3 of the total percentage of diseased plants. This marked preponderance of plants with slight root rot may not always be important. Simmonds (4), for instance, grouped healthy and slightly-lesioned plants together, apparently not attaching much importance to slight lesioning. In Manitoba, however, small lesions on the sub-crown

internode seem to have an adverse effect (Table 3) on yield. This reduction in yield arises chiefly from a reduction in the number of fruiting tillers and from a reduction in the weight of grain per spike. More pronounced reductions in the number of tillers and the weight of grain per spike accompanied moderate and severe root rot, which, in addition, reduced the length of culm. In practically all the plant samples that were collected from farm

TABLE 2.—THE PERCENTAGE OF HEALTHY PLANTS, AND OF PLANTS WITH SLIGHT, MODERATE OR SEVERE LESIONING BY COMMON ROOT ROT IN WHEAT FIELDS FROM DIFFERENT SOIL ZONES OF MANITOBA

Degree of root rot	Soil zone[1]	Year			Mean
		1939	1940	1941	
None	A1	70.8	52.7	67.1	63.6
	A2 (W)	75.7	49.2	47.2	57.4
	A2 (E)	82.8	46.2	56.5	61.9
	A3	79.5	34.8	59.8	57.8
	A5	78.1	57.4	65.8	67.1
	A7	83.8	49.4	53.4	62.2
	Mean	78.4	48.2	58.3	61.6
Slight	A1	19.4	27.4	19.3	22.0
	A2 (W)	14.3	27.1	30.6	24.0
	A2 (E)	12.8	31.2	23.7	22.6
	A3	12.7	31.3	22.6	22.2
	A5	14.4	28.7	20.2	21.1
	A7	9.9	25.7	28.7	21.4
	Mean	13.9	28.5	24.1	22.2
Moderate	A1	8.5	15.1	11.2	11.6
	A2 (W)	8.1	18.0	18.3	14.8
	A2 (E)	3.7	18.2	17.0	12.9
	A3	6.3	23.5	14.3	14.7
	A5	6.9	11.6	12.4	10.3
	A7	5.3	18.8	15.4	13.1
	Mean	6.4	17.5	14.7	12.9
Severe	A1	1.3	4.8	2.4	2.8
	A2 (W)	2.0	5.7	3.9	3.8
	A2 (E)	0.7	4.4	2.8	2.6
	A3	1.5	10.4	3.3	5.0
	A5	0.6	2.3	1.6	1.5
	A7	1.0	6.1	2.5	3.2
	Mean	1.2	5.6	2.7	3.1

[1] See footnote in Table 1.

fields, the reduction in yield per spike was attributable to a reduction in the number of kernels, not to a reduction in the weight or size of kernel. In passing, it may be said that, in plant samples containing greenish-bronze kernels, the proportion of such off-colour kernels increased with an increase in the severity of root rot.

In Table 4 are summarized the data relating to the average density of stand, the average yield of individual plants and the average yield per acre. This information is provided so as to furnish some indication of the conditions in 1939, 1940, and 1941 for the growth of wheat in the different soil zones. It is difficult, however, to relate these conditions to the presence

TABLE 3.—THE REDUCTION IN THE YIELD OF GRAIN PER PLANT, NUMBER OF SPIKES PER PLANT, AND YIELD OF GRAIN PER SPIKE CAUSED BY DIFFERENT DEGREES OF SEVERITY OF COMMON ROOT ROT IN WHEAT

Percentage reduction in yield per plant

Year	Severity of disease		
	Slight	Moderate	Severe
1939	27.5	41.5	72.6
1940	26.1	38.7	51.3
1941	23.5	32.3	48.1
Mean	25.7	37.5	57.3

Percentage reduction in number of spikes per plant

1940	18.2	25.9	28.6
1941	23.2	27.8	36.2
Mean	20.7	26.8	32.4

Percentage reduction in yield per spike

1940	10.0	16.6	24.1
1941	3.6	9.5	16.9
Mean	6.8	13.0	25.5

of root rot on the plants. In zone A1, the yield of individual plants was the highest, indicating the best conditions for growth, while, in zone A7, the yield was usually the lowest, indicating the poorest growing conditions. The difference in yield of individual plants may be partly accounted for by the fact that the plant population in zone A1 was much less dense than in zone A7. In spite of this difference in density of stand and in the individual yield, the percentage of plants with root rot (Table 1) on an average was about the same in these two soil zones. Other factors, no doubt, played an important part. The soil in zone A1 was found to be sandy, low in nitrogen, and phosphorus, and subject to drifting. In zone A2(W) conditions were somewhat similar to those in zone A1, except that the soil was black instead of brown, indicating a greater organic matter content. Zone A2(E) was slightly deficient in phosphorus. Zone A3 was, in general, highly salinized,

and subject to soil erosion by wind and rain. The soil in zone A5 appeared to be good, except that occasionally organic matter was deficient or not well distributed. Zone A7 was very high in lime. Actually the conditions for growth in these zones were not very good, a fact which probably accounted for the prevalence of root rot on the crops grown there.

TABLE 4.—THE AVERAGE NUMBER OF PLANTS IN A FIELD SAMPLE AND THEIR AVERAGE YIELD, TOGETHER WITH THE AVERAGE YIELD OF GRAIN PER ACRE IN DIFFERENT SOIL ZONES OF MANITOBA

Number of plants in sample (10 m. of drill row)

Soil zone[1]	Year			Mean
	1939	1940	1941	
A1	308.3	315.9	301.6	308.6
A2 (W)	387.8	455.1	347.4	396.7
A2 (E)	399.1	366.2	382.1	382.5
A3	335.0	416.5	328.0	359.8
A5	411.7	410.7	352.0	391.4
A7	404.0	501.4	489.9	465.2
Yield of individual plants				
	gm.	gm.	gm.	gm.
A1	0.791	1.060	1.152	1.001
Z2 (W)	0.567	0.423	0.741	0.577
A2 (E)	0.623	0.749	0.783	0.718
A3	0.786	0.575	1.121	0.827
A5	0.772	0.942	1.094	0.921
A7	0.483	0.544	0.526	0.517
Yield per acre				
	bus.	bus.	bus.	bus.
A1	24.04	33.02	34.26	30.44
A2 (W)	21.68	18.98	25.38	22.01
A2 (E)	24.56	27.10	29.51	27.05
A3	25.97	23.66	36.26	28.63
A5	29.52	38.15	37.98	35.21
A7	19.24	26.89	25.41	23.84

[1] See footnote in Table 1.

DISCUSSION

The results of the present investigation show, if the methods of making the necessary determinations are correct, that the annual loss from common root rot in Manitoba is in the neighbourhood of 12%. The method used in determining this loss is open to certain criticisms, particularly in respect to the way in which the fields of wheat were sampled, but it seemed to be the only one that was practical under the circumstances of the investigation.

It was necessary to sample many fields, and the time allowed by the rapidity with which the crops ripened did not permit much time to be spent in any particular field.

A point also open to criticism is the method of calculating the loss in yield from common root rot. Diseased plants undoubtedly yielded less than healthy plants, but there is some question as to whether or not the differences in yield were entirely attributable to the presence of root rot. It is possible that the healthy plants profited somewhat in their competition with diseased plants for food and moisture, and that their yield per plant was higher than it would have been if all the plants had been healthy. In the fields examined, the severely diseased wheat plants among a dense stand of healthy plants were always less vigorous than similarly affected plants in comparatively light stands. It seemed that, in the dense stands, the diseased plants were actually being smothered by their healthy neighbours. As healthy and diseased plants occurred more or less at random in the fields, it was impossible to determine what the yield per plant would have been had all the plants been healthy; and, hence, it was impossible to determine to what extent the yield of the healthy plants was increased as a result of reduced competition from the diseased plants.

There is some doubt concerning the role played by weeds in wheat fields attacked by common root rot. It is a well-known fact that weeds reduce the yields of cultivated plants by competing with them for food and water. When a wheat plant is weakend by root rot, it is less well equipped than a healthy wheat plant to withstand the ill effects of such competition and consequently becomes weakened even further. Actually, in wheat fields with common root rot, a vigorous weed may effectively retard or even prevent the growth of a diseased wheat plant near which it grows. On this account, the weed in effect replaces the diseased wheat plant in providing competition with neighbouring healthy wheat plants and, as this competition is usually vigorous, the healthy wheat plant probably does not benefit at all from the reduced competition from a diseased wheat plant as would be the case if the weed was absent. Competition from weeds would seem to cancel out any improved nutritional conditions afforded the healthy wheat plants by the presence of the weaker, diseased wheat plants, while, at the same time, exerting a detrimental influence on the diseased plants themselves. It would seem, therefore, that, in weedy fields comparatively free from weeds, and that, as in Manitoba the percentage of weedy fields is large, the present estimate of loss from common root rot is not too high.

SUMMARY

Common root rot of cereals and grasses is widespread in Manitoba. During the period 1930 to 1941 inclusive, no wheat field in the province was found absolutely free from the disease. The average percentage of diseased plants and the average reduction in yield for the 3 years, 1939, 1940, and 1941, was estimated at 38.3% and 12.1%, respectively. An average for the 3 years showed that a slight attack by common root rot reduced the yield of individual plants by 25.7%, that a moderate attack reduced the yield by 37.5%, and that a severe attack reduced the yield by 53.3%.

Yields were decreased as the result of a reduction in the number of fruiting tillers and in the number of kernels per spike. Because the proportion of slightly diseased plants was usually high, most of the loss occurred in this class of plants.

The severity of common root rot in any one year varied greatly from soil zone to soil zone. There was no tendency, however, during the 3 years of this investigation, for the disease in severe form to be confined to any one soil zone.

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THE EFFECTS OF WHEAT GERM AND CORN GERM ON THE FEEDING VALUE OF CEREAL GRAINS FOR HOGS

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A series of feeding tests at this station during the past six years has indicated that corn and also wheat when fed as the basal part of the market pig ration result in the production of an excessively fat carcass and a rasher pattern of fat and lean distribution less desirable than from barley feeding. From other studies with hogs and with rats, it seems probable that wheat germ and perhaps also corn germ may contain a factor or factors which facilitates the synthesis of and/or deposition of body fat from dietary carbohydrate.

The position of wheat in Canadian agriculture gives special importance to information relative to its nutritive properties and peculiarities, and the hereinafter described test was designed to study the role which the germ of wheat may play in determining the food value of this cereal.

METHODS OF INVESTIGATION

General

To test the hypothesis that the special fattening properties of wheat and corn are due in part to substances in the embryo portion, it was planned to supplement germ-free barley with wheat germ and with corn germ; germ-free wheat with corn germ; and germ-free corn with wheat germ. In a parallel series, rations consisting (for the basal part) of each of these 3 grains were fed, as well as a third series employing germ-free samples.

Animals

Purebred Yorkshire pigs weaned at 56 to 60 days and started on test between 65 and 70 days of age were used. A minimum initial weight of 35 pounds was also demanded to exclude any obviously poor-doing animals. The design provided for one test using fall-born and a replicate using spring-born pigs. In each test the sexes were distributed to have equal numbers in each lot. Within these restrictions, the 120 pigs employed were alloted at random to individual pens, 12 pigs to each of 10 feeding lots.

Feed Mixtures

All feed mixtures were identical as to the protein-mineral supplement, the percentage make-up of which was: 40 meat meal, 25 linseed oilmeal, 15 fish meal, 10 bone meal, 5 limestone, 5 salt. Potassium iodide was incorporated at 0.2 ounce per 100 pounds of supplement.

Rations fed until the pigs reached 100 pounds weight consisted of 85 parts basal feed plus 15 parts of the above supplement. At the 100-pound weight, pigs were changed individually to the B ration, which differed from the first (A) ration only in containing 10% instead of 15% supplement. The B ration was fed until the pigs were marketed at 200 pounds. While on the A ration, each pig received daily 15 cc. of a feeding fish oil of 2000 A and 400 D potency.

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The basal feeds or mixtures in the several lots were as follows:

Lot I —Entire No. 2 yellow corn.
Lot II —Degermed corn—table corn meal, Ogilvie Flour Mills.
Lot III —Degermed corn 90% plus wheat germ 10%.
Lot. IV —Entire No. 2 amber durum wheat.
Lot. V —Degermed wheat—wheat hearts, Ogilvie Flour Mills.
Lot VI —Degermed wheat 97.5% plus corn germ 2.5%.
Lot VII —Entire No. 1 feed barley.
Lot VIII—Degermed Barley—pearl barley, Ogilvie Flour Mills.
Lot IX —Degermed barley 97.5% plus wheat germ 2.5%.
Lot X —Degermed barley 97.5% plus corn germ 2.5%.

The basis for the proportions of germ to be used was the percentage of embryo in the entire grain. Thus since in corn grain the embryo (i.e. the germ separation used) represented 10% of the weight of the kernel, one part of wheat germ was added to 9 of degermed corn so that the "remade" grain had its original proportion of embryo. Other basis could with equal justification have been used. Results obtained in this test must obviously be interpreted within the design employed.

Records

Both the weights of the pigs and their feed consumption were recorded every 14 days. The data presented herewith, however, apply to the complete feeding period from the start of the test to time of marketing. Carcass data were secured through the co-operation of the Marketing Service of the Department of Agriculture, whose graders cut and examined each carcass according to the plan followed in the case of Swine Advanced Registry pigs; and of Canada Packers, who kindly made available necessary abattoir equipment for examination and for freezing the sections in addition to absorbing the losses from the cutting of the carcasses.

Statistical Analysis

The design of the trial was such than an analysis of the variance was possible according to the following scheme:

TABLE 1.—SCHEME OF STATISTICAL ANALYSIS APPLIED TO ITEMS FOR WHICH DATA WERE RECORDED

Source of Variance	Degrees of freedom		
All causes—120 pigs			119
Between 40 subgroups			
2 sexes		1	
2 seasons		1	
10 rations		9	
Interaction			
Sex × Season	1		
Sex × Ration	9		
Ration × Season	9		
Sex × Ration × Season	9	28	39
Within subgroups (error)			80

RESULTS

The results of this test are summarized in Table 2 which gives the essential data for each feeding group.

It will be noted that in Table 2 only the average values for each group are given. However, from the variability of the individual animals, there has been calculated the difference between the averages of 2 groups in any item being compared (as daily gain, carcass score, etc.), which would be expected to occur once in 20 times by chance alone[3]. This figure, called the "necessary difference", is the allowance which must be made for variation due to factors other than ration differences. The odds are 19 to 1 that where differences between 2 group averages exceed the "necessary difference" for that item, there is a real effect of kind of ration. With this in mind, the data may be examined in some detail.

Rate of Gain

Rate of gain is indicated by the observed daily gains, by the gain adjusted for equal initial weight of pig and equal feed intake, and by number of days of feeding needed to get the pigs to market weight. The average daily gain for the whole test was 1.27 pounds; against which we may set figures of 0.82 pound and 0.92 pound for pigs on degermed corn and degermed wheat respectively; and 1.61 pounds and 1.57 pounds for entire barley and entire wheat respectively. There can be no doubt of the nutritional significance of the germ of these two cereals. For some as yet unexplained reason, loss of the germ from barley is much less serious, resulting in a decline in gain of but one-quarter of a pound per day.

Expressed in terms of feeding period, the use of degermed instead of entire cereals in these rations resulted in an increase equivalent to 60, 80, and 18 days feeding for corn, wheat, and barley respectively. It should be noted that some of the pigs on the degermed corn and degermed wheat rations were actually sent to market under weight, because they were making little if any gain at all. Had the test been carried until these pigs reached 200 pounds, the average gains for their lots would have been still lower.

Efficiency of Ration

If the differences in gains traceable to differing initial weights of pigs ($b_1 = 0.0189$) and to differing feed consumption during the test ($b_2 = 0.2765$) are taken into account, it is evident that appetite failure was not the only cause of the slowing of the gains on the degermed wheat or barley, for the feed efficiency (measured by "adjusted gains") was greater in all cases when the wheat germ was present. Furthermore, the addition of wheat germ to both degermed corn and degermed barley caused a definite increase in gains per unit of feed eaten. (Lots I *vs.* III; VIII *vs.* IX). On the other hand, corn germ was not an effective supplement to degermed wheat (Lot V *vs.* VI) or to degermed barley (Lot VIII *vs.* X).

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[3] Necessary difference between means $= \frac{\sigma}{\sqrt{n}} \times \sqrt{2} \times t_{p=.05}$.

TABLE 2.—EFFECTS OF WHEAT AND CORN GERM ON THE FEEDING VALUE OF CEREAL GRAINS

Character		Lot I Entire corn	Lot II Degermed* corn	Lot III Degermed Corn + wheat germ	Lot IV Entire wheat	Lot V Degermed* wheat	Lot VI Degermed wheat + corn germ	Lot VII Entire barley	Lot VIII Degermed barley	Lot IX Degermed barley + wheat germ	Lot X Degermed barley + corn germ	Nec.† dif. between lots	Male	Female	Nec.† dif. between sexes
Observed daily gain	lbs.	1.10	.82	1.35	1.57	.92	1.09	1.61	1.34	1.51	1.43		1.35	1.20	
Daily feed	lbs.	4.99	3.89	4.52	5.53	3.70	4.26	5.81	5.26	5.51	5.38		4.92	4.85	
Adjusted daily gain‡	lbs.	1.06	1.09	1.45	1.39	1.25	1.27	1.36	1.24	1.33	1.30	.09	1.35	1.20	.04
Days fed		144	170	111	102	161	142	98	116	103	114	10.5	107	125	5.24
Shipping weight	lbs.	200	173	198	203	183	198	202	202	201	202	5.13	196	204	2.56
Carcass length	ins.	30.0		29.6	30.4		29.6	30.2	30.4	30.1	30.3	.6	29.8	30.3	.3
Shoulder fat	ins.	2.0		2.0	1.8		1.8	1.7	1.8	1.9	1.8	.16	1.8	1.8	.08
Maximum belly	ins.	1.9		2.1	1.6		2.0	1.8	1.8	1.9	1.9	.13	1.9	1.9	.07
Belly grade§		3.2		3.4	2.3		3.2	1.7	2.3	2.4	2.7	.59	3.0	2.3	.29
Ham Grade—A		4		4	7		4	7	6	4	6		20	22	
B		7		7	5		8	5	6	7	6		27	24	
C		1		1						1			1	2	
Carcass score	%	59		52	71		54	77	69	64	63	8.36	61	66	4.18
Area loin	sq. in.	5.1		4.7	4.9		4.4	5.4	4.9	4.8	4.7	.45	4.6	5.1	.23
Percent lean	%	37		35	40		35	44	39	37	39	3.63	37	39	1.81

*Carcass data incomplete, see page 81.

† Necessary difference $= \frac{\sigma}{\sqrt{n}} \times \sqrt{2} \times t_{.05}$.

‡ Gains adjusted by partial regression to equal initial weight ($b_1 = .019$ and equal feed intake ($b_2 = .276$).

§ Belly grade ranked from 1 (excellent) to 6 (poor).

Why corn germ was less effective in improving the gains per unit of feed eaten may perhaps be postulated from its content of certain parts of the vitamin B complex as compared to wheat germ.

Vitamin	Wheat germ	Corn germ
Thiamin gamma/gm.	27.9	6.5
Riboflavin gamma/gm.	8.2	3.8
Pantothenic acid gamma/gm.	18.1	11.0

It is true that more wheat germ was added to degermed corn than there was of corn germ added to degermed wheat, so that the quantity of vitamin B added was not equal in these two cases. But in the case of degermed barley equal amounts of corn or wheat germ were used. The wheat germ was more effective in raising rate of gain than was corn germ. The difference in ration efficiency was not significant though actually the wheat germ stood above corn germ. Since, however, the degerming of the barley caused much less nutritional damage, the comparative effects of wheat *vs.* corn germ supplement might not be very striking.

The question of feed efficiency and its relation to the germ fraction of the grains is further brought out by arranging the rations in descending order of gains made on equal feed intake:

Table 3.—Relative feed efficiency of rations

Ration	Relative live weight increase
Degermed corn plus wheat germ	137
Degermed wheat plus wheat germ	131
Degermed barley plus barley germ	128
Degermed barley plus wheat germ	125
Degermed barley plus corn germ	123
Degermed wheat plus corn germ	120
Degermed wheat	118
Degermed barley	117
Degermed corn	103
Degermed corn plus corn germ	100

Feed Intake

Animals on this test were full fed. Differences between lots in feed intake reflect differences in appetite. Evidently entire barley, degermed barley plus wheat germ, degermed corn plus wheat germ, and entire wheat were highly acceptable. In view of the known effect of thiamin on appetite, one might postulate that the higher thiamin content of these 4 rations

accounted for the high food intake in these lots. The results with degermed barley plus corn germ may have been tempered by the relatively high feeding value of degermed barley as compared to the other two grains.

Shipping Weight

The pigs in this test were marketed whenever they individually reached a predetermined live weight. The average shipping weight for all pigs was 201 pounds. As will be seen from Table 2, the male pigs were shipped at an average of 196 pounds and the females at 204 pounds. This was done deliberately in an attempt to correct the tendency for male pigs to be penalized for excessive fatness if marketed at equal weights with the females. This plan was reasonably effective in equalizing the carcass grades, but carcass scores, which include particularly size of eye of lean not considered in carcass grade, were still significantly below those for females.

Carcass Excellence

At the outset, it should be noted that no carcass data are included for the groups fed degermed corn or degermed wheat. There were several animals in each of these lots that were gaining so slowly that there seemed little hope of getting them to market at all. Accordingly when the trial was discontinued, these pigs were placed on other feed to be finished for market. The shipping weights shown for these lots are the figures to the close of the feeding on the experimental diet.

In general deficiencies in carcass excellence were traceable to the relative fatness. This is seen in several carcass measurements but best in "belly grade" in relation to "carcass score", "% lean" and to "thickness of belly". It will be noted that on the basis of carcass grade, the entire wheat and entire barley lots each had 58.5% grade A. In spite of this the entire wheat-fed hogs carried only 40% lean as compared to 44% lean in entire barley lots, and the eye of lean in the rasher was 4.9 square inches as compared to 5.4 square inches in the barley group. Thus wheat rations still produced the fatter carcasses. Had 10 pounds more weight been put on the male pigs it is our belief from examination of the carcasses that more wheat-fed grade A hogs would have been degraded to B class than would have been the case with barley-fed animals. It is of interest to note, however, that there appeared to be some advantage in considering sex in fixing marketing weights. We are unable to explain the significantly thinner bellies found on the wheat-fed pigs. It is not in accordance with previous or subsequent tests, nor does it correlate with other measurements which all indicate fatter carcasses in wheat-fed hogs.

The effect of adding wheat germ to degermed barley is evident in thicker bellies, and deeper shoulder fat, smaller percentage of lean, fewer A carcasses and smaller carcass score. Corn germ on the other hand has shown little effect in changing carcass characteristics over those produced on degermed barley without germ additions.

DISCUSSION

These data leave no doubt of the importance of the germ fraction in influencing the nutritional values of the cereal grains. Specifically it has been shown that much of the vitamin B complex is concentrated in the

embryo. Loss of this group of vitamins from the grains through milling processes alters materially the nutritive properties of the residue. On the other hand, milling fractions of cereals made up largely of the germ of the grain are likely to exhibit special nutritive properties when added to ration combinations, the nature and extent of which may be expected to be characteristic of the particular grain involved. It appears probable that these special properties are related to and perhaps proportional to the amounts of one or more members of the vitamin B complex rather than to any particular proteins or minerals present. This view is supported by rat feeding tests at this station (Crampton and Ashton, 1942; in press) in which diets comparable to the wheat lots of this study were compared to others in which synthetic vitamin B supplements replaced the cereal germ additions. The conclusions from that trial were (in part), "Corn germ and wheat germ are of markedly different nutritional value as supplements to a basal diet of wheat endosperm fortified with adequate proteins, minerals and vitamins A and D. . . . . The intake through wheat germ of thiamin was about one-half, and of riboflavin one-third that fed in the (synthetic) B mixture. Feed intake was 34% greater with wheat germ supplement and 60% greater with the "B" mixture than in the check lot. Gains per unit of food eaten as a result of these supplements were 40% greater than in the check lot. Corn germ stimulated only an 18% increase in feed consumption and failed to improve the efficiency of the diet." (In these rat tests, wheat germ or corn germ was added as 2.1% of the total air dry feed.)

That one of the reasons for the fatter carcasses produced on diets in which wheat germ is present, is related to the fat synthesizing properties of thiamin seems evident from the results of tests on samples of the wheat germ and corn germ from our laboratory by McHenry and Patterson, School of Hygiene, University of Toronto. Wheat germ (4%) as the only source of any vitamin B components in their standard fat-free basal diet, produced in 7 days on amount of body fat equal to about 3 times that found in rats at the end of the 28 day preliminary feeding on the basal diet alone. Corn germ, however, failed to stimulate fat synthesis. They conclude[4], ". . . . There is equally good evidence for fat synthesis in group three (wheat germ) . . . No fat synthesis was produced by corn germ and this means, to us, almost complete absence of thiamin . . ."

The significance of these findings lies partly in the fact that a considerable number of cereal foods prepared for human consumption are carefully degermed during manufacture, usually to improve the keeping qualities of the product. The milling by-products containing the germ frequently find their way into animal feeds. Shorts from wheat, for example, contain about 40% of germ. Fed to dairy cattle, its vitamin B value is wasted. Fed with wheat or barley it may cause excessively fat carcasses. Fed with corn it might markedly improve the feed intake and hence the rate of gain of a corn ration, though there might be a tendency again toward fat carcasses.

[4] Correspondence to authors.

CONCLUSIONS

The nutritive properties of the cereal grain are in part dependent on the composition of their embryo fractions, probably specifically with their content of members of the vitamin B complex.

There appear to be differences between the germs of different cereal grains with respect to their nutritive properties. Wheat germ has an especially high value in supplementing the endosperm of corn, barley, or wheat.

Because of the tendency of wheat germ to stimulate or facilitate synthesis and deposition of body fat from dietary carbohydrate, it seems possible that use might be made of this characteristic to regulate, to some extent, the utilization of the food consumed by animals.

MANGANESE DEFICIENCY IN SOILS AND CROPS

II. THE USE OF VARIOUS COMPOUNDS TO CONTROL MANGANESE DEFICIENCY IN OATS[1]

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Marked response in the control of manganese deficiency of Alaska oats was obtained in 1940 by the writer (1) using a foliage spray of 1% $MnSO_4$. These oats were grown in a range at the Ontario Agricultural College, where oats invariably exhibited severe symptoms of manganese deficiency. Opportunity was afforded, during 1942, to supplement the earlier studies, on the aforementioned range, and on a large field of muck soil at Wallaceburg, Ontario, where oats are grown for processing into powdered grass.

INVESTIGATIONS

A. Experiments on the Range at the Ontario Agricultural College

Investigations were conducted to determine the optimum foliage spray concentration, with and without a spreader and sticker; the relative efficiency of foliage dusting with various manganese compounds; the minimum amount of manganese necessary as a soil application, and the contributory effect of gypsum and sulphur; also, the relative efficiencies of a fertilizer grade of manganese sulphate and of certain manganese ores when compared with pure manganese sulphate.

Materials and Methods

Erban oats were sown on April 30, in the manganese-deficient soil in plots, each consisting of 4 rows, 8 inches apart and 66 feet long. Check plots, 5 weeks after sowing, gave the following analysis expressed as lb. per acre: phosphorus high (P_2O_5 = 130 using 0.05 N HCl, modified Thornton); potassium high (K_2O = 450, Thornton); calcium medium high (Ca = 1000, Spurway); magnesium high (Mg = 56+, Spurway); free carbonate = 0. In reaction the soil was very slightly alkaline (pH 7.2). The soluble manganese content of this soil was found to be 0.9 p.p.m. while that of neighbouring soil where manganese deficiency of oats does not occur was 4.0 p.p.m. The manganese determinations were made by the Soils Division, Chemistry Dept., Ontario Agricultural College, by a technique as yet unpublished.

The manganese compounds included: manganese sulphate ($MnSO_4 . 4H_2O$); Tecmangam, a manganese fertilizer containing 66.99% $MnSO_4$. 10.00% $(NH_4)_2SO_4$, 22.40% $MgSO_4$, along with traces of eleven other elements; and three manganese ores which contain, among other elements, manganese in the oxide form, and designated as Frit JW325 (30% Mn),

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Frit (FW325 (7.07% Mn), and Frit 12% Mn (12% Mn). The Tecmangam and Frits were supplied by The Harshaw Chemical Company, Cleveland, Ohio.

Soil applications of the various manganese compounds (see Table 1) were made by sifting the compound uniformly within a trench 6 inches deep, filling the trench with earth and sowing the oats directly above. Gypsum and sulphur were applied, separately, on certain of the plots, alone and in combination with Tecmangam. They were applied at the rate of 1000 lb. per acre by surface broadcasting, following which the soil was disced to a depth of about 6 inches, then levelled. This was done prior to manganese application or sowing.

Foliage spray applications of $MnSO_4$ and Tecmangam were made with a knap-sack sprayer on June 5, five weeks after sowing. At this time the oats were slightly chlorotic, an early symptom of manganese deficiency. The $MnSO_4$ and the Tecmangam were applied at rates varying from $\frac{1}{4}\%$ to 5% (see Table 1) with and without a spreader and sticker (bentonite clay $\frac{1}{2}\%$ and soap 1 oz. per gallon).

Dust applications of all the manganese compounds were made on the respective plots, on June 6. The dust was applied by means of a hand duster in the early morning when the foliage was wet with a heavy dew. The amount of dust applied was made equivalent in manganese content to that of a 1% $MnSO_4$ spray; this resulted in a very heavy load of the Frit dusts, especially those of a low manganese content.

Each plot was divided at harvest as 3 replicates. The sheaves were hung in a barn until thoroughly dry then weighed, threshed, and the resultant grain cleaned of all chaff and weighed.

TABLE 1.—DATA ON THE RESPONSE OBTAINED FROM THE USE OF VARIOUS COMPOUNDS TO CONTROL MANGANESE DEFICIENCY OF ERBAN OATS

Method of application	Compound and rate of application		Data on the response obtained is given as average of three replicates; where significant variations occurred the extremes are included			
			Plant height/ inches	Sheaf weight (air dry) lb./acre	Grain weight bu./acre	Remarks
—	Check		20 (15–30)	1500	3 (0–4)	Excess tillering gave high sheaf weight; mostly leaves
Foliage dust	Frit 12% Mn	Dosage equal in Mn content to 1% $MnSO_4$ spray	28 (21–34)	2344	19	Severe symptoms of manganese deficiency
	Frit JW325		25 (21–32)	1641	8	
	Frit FW325		26 (23–34)	1641	8	
	Tecmangam		39	3516	38	Considerable foliage burning especially with $MnSO_4$. New growth of normal colour
	$MnSO_4$		40	3117	30	

* The −S and +S within the foliage spray technique refer to the absence and presence, respectively, of a spreader and sticker along with the manganese spray.

TABLE 1.—DATA ON THE RESPONSE OBTAINED FROM THE USE OF VARIOUS COMPOUNDS TO CONTROL MANGANESE DEFICIENCY OF ERBAN OATS—*Continued*

Method of application	Compound and rate of application		Data on the response obtained is given as average of three replicates; where significant variations occurred the extremes are included: Plant height/ inches	Sheaf weight (air dry) lb./acre	Grain weight bu./acre	Remarks
Foliage spray	Tecmangam ½%	−S*	33	2273	14	Later stages of growth not as vigorous as in in those plots where a heavier spray concentration was used
		+S	36	3281	31	
	$MnSO_4$ ½%	−S	36	2742	21	
		+S	39	3352	34	
	Tecmangam 1%	−S	39	3281	30	No foliage burning by the spray
		+S	39	3914	39	
	$MnSO_4$ 1%	−S	37	3281	31	
		+S	40	3586	34	
	Tecmangam 2%	−S	41	3984	37	Some burning of foliage observed but new growth normal
		+S	42	4219	44	
	$MnSO_4$ 2%	−S	43	3750	37	
		+S	43	4453	46	
	Tecmangam 5%	−S	43	3984	41	Severe burning after spraying which checked growth temporarily
		+S	41	4383	44	
Soil application/lb. per acre	Frit 12% Mn 250		22 (20–34)	1172	3	Severe symptoms of manganese deficiency
	Frit JW325 250		22 (20–31)	1172	7	
	Frit FW325 250		22 (20–31)	1641	9	
	Tecmangam 370		40 (35–45)	3914	33 (13–46)	Irregular stand
	Tec. 370 + Gypsum 1000		35 (15–42)	2051	12 (3–22)	
	Tec. 370 + Sulphur 1000		45	5927	58	Growth of normal appearance
	Tecmangam 925		47	5555	53	
	Tec. 925 + Gypsum 1000		43	5086	63	
	Tec. 925 + Sulphur 1000		47	6633	79	Luxuriant growth
	Tecmangam 1850		49	6094	63	No evidence of manganese toxicity
	$MnSO_4$ 250		42 (40–44)	3750	33 (20–51)	Irregular stand
	$MnSO_4$ 625		48	6797	76	Luxuriant growth
	Gypsum 1000		—	—	—	Yields not recorded; no improvement over check plots
	Sulphur 1000		—	—	—	

Observations and Conclusions

Data on the response obtained by the various manganese compounds and the techniques of application are presented in Table 1. The yields are given on an acreage basis as an average of the 3 replicates except where wide differences between replicates occurred; in the latter instances the extremes of the replicates are included along with the average.

The check plots began to show chlorosis about 5 weeks after sowing. Typical symptoms of manganese deficiency then developed. In some portions of the plots no heads developed while in others spindly heads were formed which, as indicated in Table 1, yielded little grain. Excess tillering of the oats resulted in a relatively high sheaf weight in proportion to grain weight.

Figure 1. Response of Erban oats to soil applications of various compounds to correct manganese deficiency. The plot to the left received gypsum at 1000 lb. per acre; centre was a check; to the right received Tecmangam at 925 lb. and sulphur at 1000 lb. per acre. The portion of the plot shown at upper extreme left received a foliage spray of $\frac{1}{4}\%$ $MnSO_4$ without a spreader and sticker.

The Frits gave only a minor response when dusted on the foliage even though the dosage was sufficient to give an equivalent in manganese content to that of a 1% $MnSO_4$ spray. The Tecmangam and $MnSO_4$ applied as dusts gave results comparable to a 1% spray of these compounds but rather severe foliage burning occurred. This burning might have been avoided had an inert dust diluent been used.

All plots receiving the various foliage spray concentrations of Tecmangam and $MnSO_4$ showed an initial response about 10 days after application, and, a few days later, presented a sharp contrast to the check plots because

of their dark green colour and more rapid rate of growth. Foliage burning by the 2% sprays camouflaged the initial response to some extent; this burning was most evident in the 5% Tecmangam spray plot, where growth was temporarily checked. Later field observations, substantiated by the yield data (see Table 1) indicated that of the 4 spray concentrations used, the 2% spray was the most efficient. In all instances a better yield was obtained when the spreader and sticker was added.

Soil applications of the Frits gave little to no response. Lack of sufficient material prevented testing these Frits at higher rates of application than 250 lb. per acre. The response to Tecmangam alone depended upon application rate: 370 lb. per acre gave an irregular stand with a corresponding irregularity in grain yield within different replicates; 925 lb. per acre gave a uniform stand of normal appearance while 1850 lb. per acre resulted in a luxuriant stand and the highest yield. Application at the rate of 1850 lb. per acre is probably far beyond maximum requirement but, contrary to expectations, no evidence of manganese toxicity was observed even though the compound was sown as a row underneath the seed grain.

The response to soil applications of $MnSO_4$ followed a pattern comparable to that of Tecmangam. $MnSO_4$ at the rate of 250 lb. per acre resulted in an irregular stand similar to that of Tecmangam, applied at the rate of 370 lb. per acre. This could be expected in that Tecmangam contains approximately 67% $MnSO_4$. Application of $MnSO_4$ at the rate of 625 lb. per acre resulted in a luxuriant stand and a grain yield of 76 bushels per acre.

Gypsum and sulphur were applied to the soil at the rate of 1000 lb. per acre, alone and in combination with different application rates of Tecmangam. Alone, neither gypsum nor sulphur gave any response. Any beneficial effects obtained from the use of gypsum in combination with Tecmangam are questionable. Sulphur, on the other hand, contributed markedly. Tecmangam at the rate of 370 lb. per acre with sulphur gave a slightly higher yield than Tecmangam alone at the rate of 925 lb. per acre. Sulphur along with Tecmangam at 925 lb. per acre gave the highest yield of any plot (79 bushels per acre).

A comparison of the 3 techniques of applying manganese, that is, foliage dusting, foliage spraying, and soil application, would indicate that the highest yield can be obtained by soil application. From an economic viewpoint, however, the soil application technique is open to question. Tecmangam, alone, at the rate of 925 lb. per acre, or at the rate of 370 lb. plus sulphur at 1000 lb. per acre were required to exceed the grain yield obtained by a 2% spray. The extra cost of materials for soil application would more than counterbalance returns from the increase in yield. Severe foliage burning could be expected if dusting were substituted for the 2% spray. This might be avoided, however, by including some inert dust diluent.

B. Experiments on the Use of Tecmangam to Correct Manganese Deficiency of Oats, on a Field at Wallaceburg, Ontario

Oats grown on a large flat field at Wallaceburg, Ontario, have expressed mild to moderate symptoms of manganese deficiency, especially during dry seasons. These oats are grown for processing into powdered grass. Three to 5 cuttings are usually made from 1 sowing, the first cutting being made just prior to nodal establishment.

Materials and Methods

The soil is a well decomposed muck containing a moderately high amount of organic material and considerable fine sand. Soil samples taken the latter part of April, 1942, gave the following analysis expressed as lb. per acre: phosphorus high (P_2O_5 = 150 using 0.05N HCl, modified Thornton); potassium low (K_2O = 60, Thornton); calcium medium high (Ca = 1000, Spurway); magnesium high (Mg = 56+, Spurway); free carbonates = 0. In reaction the soil was slightly acid (pH 6.5).

Plots were established in this field to ascertain the response which could be obtained by soil applications of Tecmangam applied at various rates and by a foliar dust application. Table 2 gives the different rates of application which varied from 68 lb. to 619 lb. per acre. Each plot (0.97 acres) consisted of two strips 8 feet wide and $\frac{1}{2}$ mile long with a 2-foot border left unplanted between the strips. The two strips of any one plot were not adjoining but were harvested as a single unit. Because of insufficient material, a single strip constituted the plot for the heaviest application of Tecmangam (619 lb. per acre).

Boone oats were sown on May 19, 1942, using an 8-foot seed drill. By means of a fertilizer attachment to the drill, 0-12-15 fertilizer was applied to all the plots at the rate of 200 lb. per acre. The respective soil applications of Tecmangam (see Table 2) were made by mixing the Tecmangam with the 0-12-15 fertilizer. The dust application of Tecmangam involved mixing the compound with "overs" (screenings from the powdered grass) at the rate of 5 lb. of Tecmangam to 8 lb. of "overs". This mixture was dusted on the foliage on June 13 (25 days after seeding) at the rate of 60 lb. per acre. This gave an approximate equivalent in manganese content to a 1% $MnSO_4$ spray.

The oat grass was cut by power equipment, then in the processing equipment, dried rapidly, ground, cleaned and bagged as a fine dry powder. The weight of the refined powdered grass was used to calculate the yield. The manganese content of the powdered grass was determined on a dry weight basis by a slight modification of the Willard and Greathouse method. Data were obtained from the first two cuttings only.

Observations and conclusions

Data on the yield and the manganese content of the powdered grass from the first 2 cuttings are presented in Table 2. The check plot exhibited mild symptoms of manganese deficiency at the time of the first cutting. As may be seen in Table 2, both the yield and the manganese content of the

powdered grass, obtained from the first cutting, indicated a response to soil application of Tecmangam, which was directly proportional to the rate of application.

No symptoms of manganese deficiency were evident on the check plot at the time of the second cutting. Wet weather may have influenced the availability of the natural soil manganese. Compared with the first cutting, the yield of the check plot was doubled and was even higher than that of any of the plots in which applications of Tecmangam had been made. Some response to the various rates of soil applications of Tecmangam was indicated by the yields of the second cutting. The exception to this was the plot in which Tecmangan had been applied at the rate of 272 lb. per acre. No explanation can be given by the writer for the relatively high yield of this plot. The responses obtained from the various soil applications of Tecmangam, as expressed by the manganese content of the powdered grass, were at a lower level than those obtained in the first cutting.

TABLE 2.—RESPONSE TO MANGANESE BY BOONE OATS FROM WHICH SUCCESSIVE CUTS WERE MADE FOR PROCESSING INTO POWDERED GRASS

Tecmangam[1] Application lb./acre	Yield and Mn. content of the powdered grass on a dry weight basis			
	1st cut—June 20[2]		2nd cut—July 7	
	Yield lb./acre	Mn content p.p.m.	Yield lb./acre	Mn. content p.p.m.
Check—0	374	19.9	753	17.1
Soil—68	422	21.0	777	27.3
Soil—136	425	36.2	802	21.4
Soil—272	508	49.9	1030 ?	41.9
Soil—619	684	86.7	865	54.8
Foliage dust—23	454	47.7	588	35.5

[1] Tecmangam—A commercial fertilizer containing 67% $MnSO_4$.
[2] The first cut was made just prior to jointing.

The foliage application of Tecmangam as a dust mixed with powdered grass screenings caused no foliage burning but did not have an opportunity for full expression. Response to foliage application of manganese is not visibly evident until at least 7 to 10 days after application; only 1 week elapsed between dusting with Tecmangam and the first cutting.

SUMMARY

Various techniques were employed to determine the most practical means to correct manganese deficiency of Erban oats on soil where oats normally express severe deficiency symptoms.

1. Very heavy applications of compounds containing manganese sulphate were required as soil application to correct the deficiency in Erban oats. The addition of sulphur at the rate of 1000 lb. per acre increased the yield materially and in one instance reduced the amount of manganese necessary by about two-thirds.

2. Of the spray concentrations tested, a single 2% spray of $MnSO_4$ or of Tecmangam (67% $MnSO_4$) with a spreader and sticker added, resulted in the highest yield. Some foliage burning occurred. The spray did not give as high a yield as the heavy soil applications. Nevertheless, this lower yield is more than counter-balanced by the added cost of materials for soil application.

3. Foliage dusting with manganese sulphate and Tecmangam, without a dust diluent caused severe foliage burning.

4. Three manganese ores tested as soil applications at 250 lb. per acre or as foliage dusts equivalent in manganese content to a 1% $MnSO_4$ spray gave little to no response.

Soil applications of Tecmangam at rates varying from 68 lb. to 619 lb. per acre were made on a large muck field where oats normally express mild to moderate symptoms of manganese deficiency. Successive cuts were made from these oats for processing into powdered grass.

1. Mild symptoms of manganese deficiency were evident on the checks at the time of first cutting (just prior to jointing). Both the yield and manganese content of the powdered grass indicated a response which was directly proportional to the amount of Tecmangam added.

2. No symptoms of manganese deficiency were evident on the checks at the time of the second cutting (17 days later). The manganese content of the powdered grass indicated a response to the Tecmangam but no definite correlations could be made with respect to yield.

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ADDENDUM

Erban oats were sown in 1943 on the entire range of manganese-deficient soil and on adjoining normal soil at the Ontario Agricultural College. Manganese-deficiency symptoms began to appear 3 weeks after sowing; this was earlier than usual and can possibly be attributed to a temporary period of warm dry weather. It was of interest to note that there was no evidence of response to the heavy soil applications of $MnSO_4$, either with or without sulphur, applied the previous year. In view of the relatively small amount of foliage when deficiency symptoms began to appear, 2 sprays were applied, 3 and 5 weeks, respectively, after sowing. A 240-gallon orchard power sprayer with gun attachment was used. The spray contained Tecmangam 1%, bentonite clay $\frac{1}{2}$%, and Orvus (Proctor and Gamble, Toronto) at the rate of $\frac{1}{2}$ pint to 80 gallons. Although no yield data were taken observations throughout the growing period and at harvesting time indicated no difference between oats growing on normal soil and the sprayed oats on the manganese-deficient soil. A normal crop was obtained.

STUDIES RELATING TO FERTILITY IN ALFALFA (*MEDICAGO SATIVA* L.)

I. POLLEN VIABILITY AS AFFECTED BY SEASONAL AGE OF THE PLANT[1]

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The seasonal variability in pod-setting of the alfalfa plant is quite marked, and has been reported by numerous workers. That pollen viability might be involved was thought possible, and in 1936 an experiment was conducted to determine whether the pollen viability changed with an advance in the seasonal age of the plant.

LITERATURE REVIEW

Working with 3 species of the genus *Crepis*, Poole (11) made daily counts of the good and bad pollen produced by plants from the beginning to the end of the flowering period. From these counts he came to the following conclusions. "Fluctuation in the percentages of good and bad pollen in pure species is probably not influenced by external factors but by the physiological adjustments made to flowering and senescence." "The plotted curve of good pollen grain percentages substantiates this view, indicating further that the daily fluctuation is inconsiderable in a given plant once the adjustments are made."

TABLE 1.—LIST OF PLANT MATERIAL USED

Plant designation	Strain and plant number	Varietal origin	Flower colour	Growth habit	Fertility classification
1	S_3.33.3 (4-5)	Ontario variegated	dark purple	erect	sterile
2	S_1.28.3 (9-11)	Grimm Grafton's	yellow	erect	sterile
3	S_1.32.29 (40-10)	Grimm Lyman's	light purple	erect	fertile
4	I.31.9 (21-23)	Grimm	light purple	erect	fertile
5	S_1.32.32 (47.5)	Cossack	bluish	erect	fertile

MATERIALS AND METHODS

In this study 5 individual plants were used. Table 1 includes information regarding two of the important morphological characters of the plants, as well as the varietal origin and fertility rating. All of these plants were collected and classified by Bolton (3), and were grown in a large isolation screenhouse.

With one exception, the plants are considered to be representatives of the species *Medicago sativa* L. Plant 2, which could be classed as *M. media* Pers., has yellow flowers, pods which are slightly coiled, and extremely erect stems.

[1] A portion of a thesis presented to the Committee on Graduate Studies, University of Alberta, in partial fulfilment of the requirements for the degree of Master of Science.

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Percentage pollen germination on an artificial medium was taken as a measure of pollen viability. The germination counts were made using the same method as outlined by Bolton and Fryer (4).

The medium consisted of 1½ grams of agar and 12 grams of cane sugar in 100 cc. of water. The agar-sugar solution was poured into Syracuse dishes and used as soon as cooled. Pollen was spread over the medium by artificially tripping several flowers a few inches above the surface, 2 plates being prepared for each plant. The plates were covered, and the pollen allowed to germinate for 2 hours at room temperature (20 to 23° C.), after which they were placed in a refrigerator at approximately 0° C. until such time as the counts could be made.

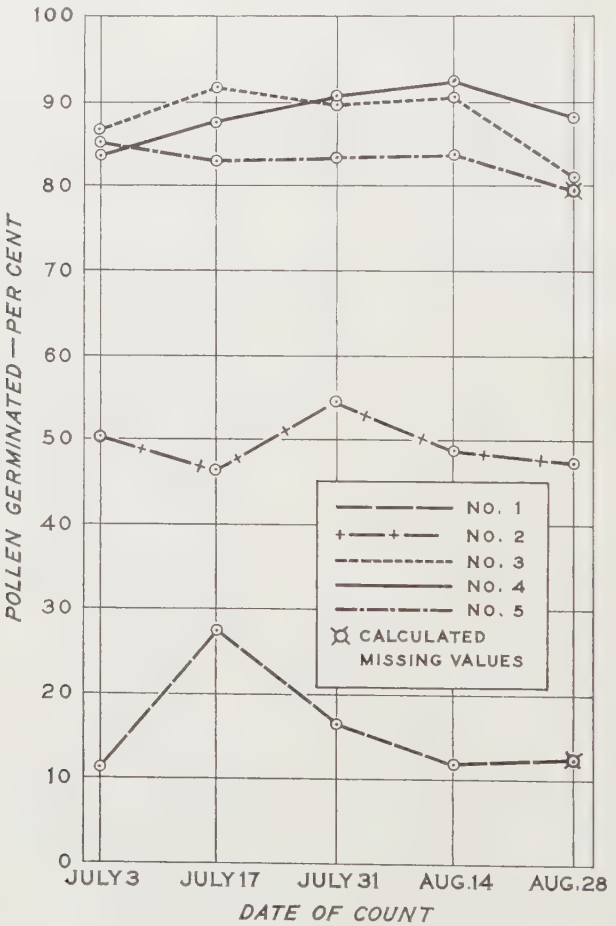

FIGURE 1. Pollen viability throughout season, expressed as percentage germination on agar-sugar medium.

Counts were taken of 100 microscopic fields for each plate, using the 16 mm. objective and 10× eyepiece. To facilitate the counting, the plates were flooded with a dilute solution of methylene blue chloride. A pollen grain was considered to have germinated if the length of the pollen tube was greater than the diameter of the grain itself.

The same procedure was followed throughout the flowering season at 14-day intervals, the pollen being spread on the agar-sugar medium at about the same time of day on each occasion.

The statistical analyses were carried out in accordance with the methods outlined by Fisher (10) and Snedecor (12). The inverse-sine transformation was applied to the percentage data following suggestions given by Cochran (8), and Clark and Leonard (6).

EXPERIMENTAL RESULTS

The plants used for this experiment were selected for a wide range in pod-setting ability, selection being based on determinations made by Bolton (3). The average percentage of pod-setting for these plants is presented below, the average being for 2 selfing tests conducted by Bolton (3) in the summer of 1935.

Plant designation	Pod setting (Per cent)
No. 1	0.00
No. 2	11.67
No. 3	22.23
No. 4	56.37
No. 5	83.35

The results obtained for the pollen viability counts are presented in Table 2 and shown graphically in Figure 1.

TABLE 2.—POLLEN VIABILITY AS AFFECTED BY SEASONAL AGE OF THE PLANT, EXPRESSED AS PERCENTAGE GERMINATION ON AGAR-SUGAR MEDIUM

Plant designation	Date	Number of microscopic fields counted	Total number of pollen grains	Number of grains germinated	Germination	
					Plate 1	Plate 2
					%	%
1	3/7/36	80	205	24	11.71	—
	17/7/36	200	1708	470	29.17	25.43
	31/7/36	150	410	67	19.28	7.69
	14/8/36	158	652	78	13.39	7.55
	28/8/36	no flowers available				
2	3/7/36	200	1863	937	47.83	52.38
	17/7/36	200	3584	1662	44.03	48.33
	31/7/36	200	2236	1233	55.70	54.54
	14/8/36	200	3338	1633	45.91	51.87
	28/8/36	200	2347	1112	49.82	45.09
3	3/7/36	200	2400	2081	87.70	85.85
	17/7/36	200	1724	1578	91.05	92.06
	31/7/36	200	1397	1252	86.05	90.95
	14/8/36	200	2325	2103	91.29	89.65
	28/8/36	200	1609	1303	81.71	80.33
4	3/7/36	200	2908	2444	82.94	85.51
	17/7/36	200	2103	1845	87.94	87.46
	31/7/36	200	1289	1166	92.41	88.66
	14/8/36	200	2149	1982	92.08	92.37
	28/8/36	200	1949	1712	87.74	87.93
5	3/7/36	200	3069	2611	83.93	86.40
	17/7/36	200	2379	1974	84.10	81.63
	31/7/36	200	1722	1433	81.19	84.51
	14/8/36	200	2591	2170	83.47	84.09
	28/8/36	no flowers available				

For purposes of analysis, the inverse-sine transformation was applied to the percentage data. Further, it was thought advisable to make two analyses because one count was incomplete and two others were missing. Table 3 gives the transformed data for all 5 plants at 3 different dates, and Table 4 for 3 plants at the 5 dates.

TABLE 3.—TRANSFORMED POLLEN GERMINATION PERCENTAGE DATA FROM TABLE 2, FOR 5 PLANTS AND 3 DATES

Plant designation	Date					
	17/7/36		31/7/36		14/8/36	
	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2
1	32.71	30.26	26.06	16.11	21.47	16.00
2	41.55	44.03	48.27	47.58	42.65	46.09
3	72.64	73.68	68.11	72.54	72.84	71.28
4	69.64	69.30	74.00	70.36	73.68	74.00
5	66.50	64.60	64.30	66.81	66.03	66.50

* Expressed as degrees, and obtained from transformation tables given by Bliss (2).

TABLE 4.—TRANSFORMED POLLEN GERMINATION PERCENTAGE DATA FROM TABLE 2, FOR 3 PLANTS AND 5 DATES*

Plant designation	Date									
	3/7/36		7/17/36		31/7/36		14/8/36		28/8/36	
	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2	Plate 1	Plate 2
2	43.74	46.38	41.55	44.03	48.27	47.58	42.65	46.09	44.89	42.19
3	69.47	67.94	72.64	73.68	68.11	72.54	72.84	71.28	64.67	63.65
4	65.57	67.62	69.64	69.30	74.00	60.36	73.68	74.00	69.47	69.64

* Expressed as degrees, and obtained from transformation tables given by Bliss (4).

The analysis of variance, in degrees, for 5 plants at 3 dates is:

Variance due to	D.F.	M.S.	F	5% point
Plants	4	2,634.3877	92.05	3.84
Dates	2	5.5908	0.20	—
Plants × Dates	8	28.6204	—	—
Residual	15	6.6708	—	—
Total	29			

The analysis of variance, in degrees for 3 plants at 5 dates is:

Variance due to	D.F.	M.S.	F	5% point
Plants	2	2,129.2827	170.13	4.46
Dates	4	23.1048	1.85	3.84
Plants × Dates	8	12.5153		
Residual	15	2.5647		
Total	29			

It is clearly seen, from the two foregoing analysis tables, that difference in pollen viability due to dates is insignificant, while that for plants is highly significant. Therefore, it is concluded that under the conditions of this experiment, the pollen viability of a given plant does not vary significantly throughout the season.

DISCUSSION

The results obtained indicate that the seasonal variation in pollen viability for a given plant is not significant. This is in agreement with the work of Poole (11) for species of *Crepis*.

It is of interest to note that Poole (11) used plants grown in the greenhouse, whereas these studies were made on plants grown outside. The temperature and humidity would doubtless be more constant in the greenhouse than in the field.

In the field, temperature varied from 36° to 94° F., and the humidity from 20% to 100% during the course of the experiment. These varying conditions, however, had little effect on pollen viability, as is shown by the results obtained.

Clarke and Fryer (7) grew clonal divisions of the same plant in the greenhouse under conditions of high and low temperatures. The actual temperatures were not specified. They found that the temperature had no effect on the amount of poor pollen formed by the plant. Results also indicate that the variable percentages of viable pollen produced by the individual plants may be, in part, responsible for the differences exhibited in pod-setting.

This same view has been expressed by several workers. Engelbert (9) was of the opinion that 22.5% sterile pollen was of little importance when a plant produced an abundance of pollen, but that the amount and sterility of pollen may be partly responsible for differences in seed-setting exhibited by different plants. Brink and Cooper (5) concluded that the amount of abnormal pollen may occasionally be large enough to limit seed-setting. Armstrong and White (1) believe that pollen sterility is a factor which influences the pod-setting and the number of seeds per pod. Bolton and Fryer (4) report that there is no general correlation between pollen viability and pod-setting, even though there seems to be a relationship in some instances.

SUMMARY

Pollen viability counts were made on 5 alfalfa plants at intervals throughout the flowering season in 1936 at Edmonton, Alberta. The results of these counts indicate that there is no significant difference in pollen viability throughout the season on any one plant, but that differences between plants may be highly significant. Therefore, the seasonal variations in pod-setting cannot be due to changes in pollen viability.

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